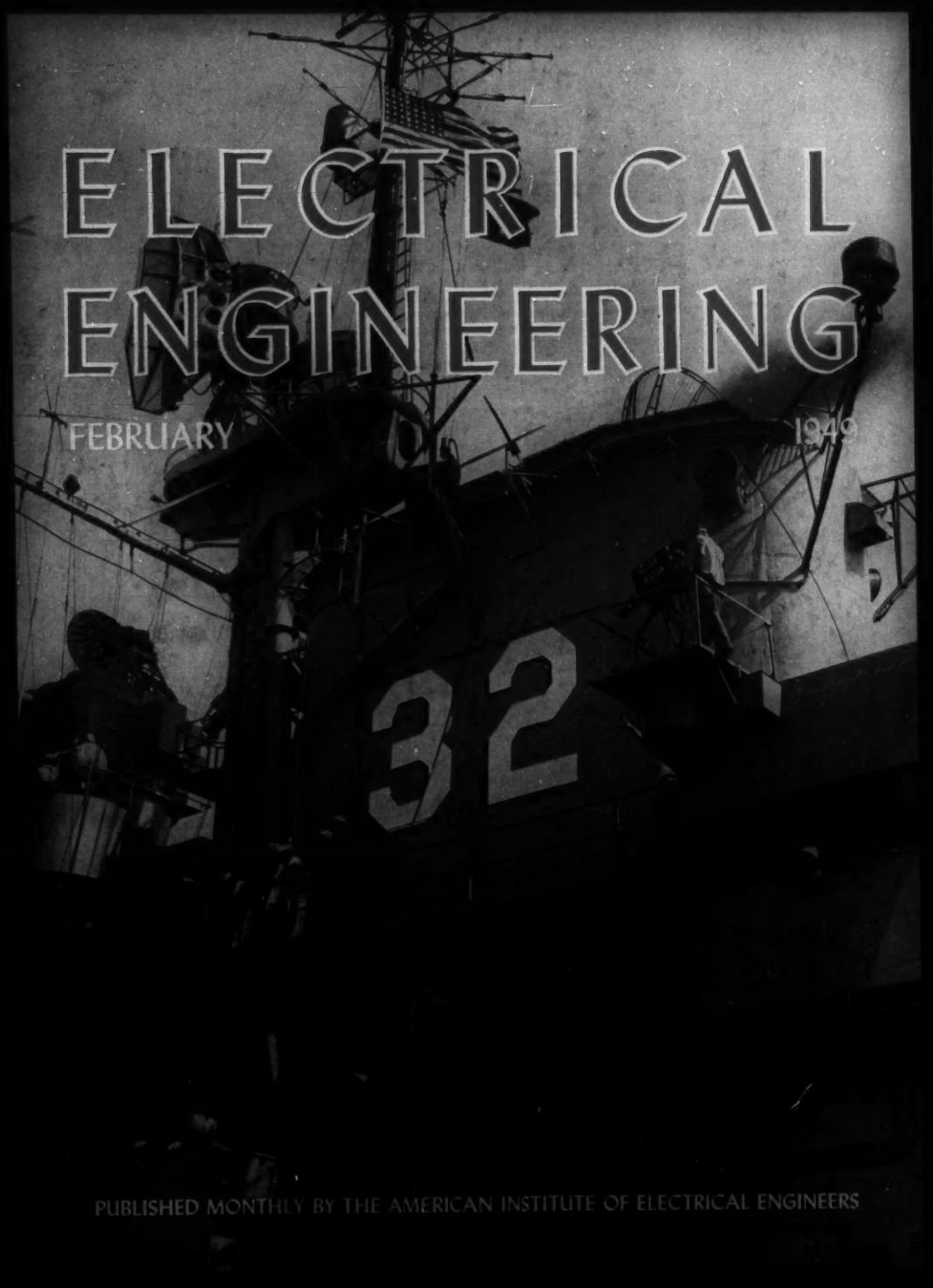
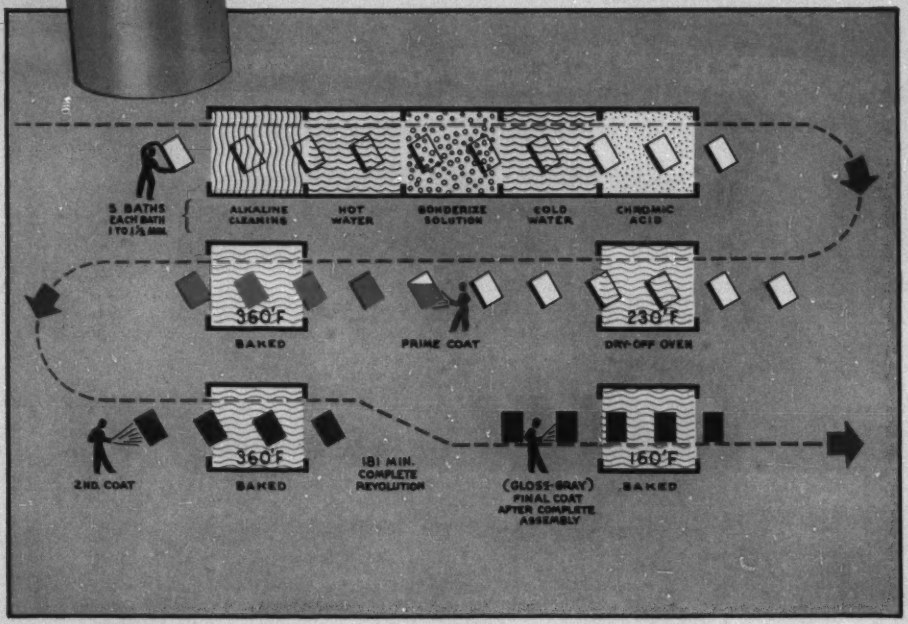


PUBLISHED MONTHLY BY THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

Spra-Bonderized— to Beat SEVERE WEATHER, CORROSION



Allis-Chalmers Distribution Transformers

TRANSFORMERS get *Lasting Protection* with Spra-Bonderized surface treatment . . . a hot dip phosphate process which converts metallic surface of transformer tank to a non-metallic phosphate coating.

Because this coating is bonded integral with the metal, it effectively retards corrosion, even in the extreme case of abrasion or scratching of paint film. After Spra-Bonderizing, tank gets three coats of tough, baked-on enamel.

A lasting finish is just one advantage of specifying Allis-Chalmers distribution transformers. You also benefit through 12-point quality construction, reductions in size and weight, and through selection from a *complete line* of standard ratings. Ask your nearby A-C sales representative for the complete story. Or write for bulletin 61B6159A.

ALLIS-CHALMERS, 931A SO. 70 ST. MILWAUKEE, WIS.

599

ALLIS-CHALMERS

Pioneers in Power and Electrical Equipment from Generation through Utilization

ELECTRICAL ENGINEERING

Registered United States Patent Office

FEBRUARY
1949

The Cover: "Task Force TV," a 100-minute telecast on August 29, 1948, originating aboard the aircraft carrier *USS Leyte* at sea off Long Island and televised by station *WNBT* of the National Broadcasting Company. In this telecast, first of its kind, some 2,000,000 viewers in the northeastern part of the United States watched the flat-top undergoing mock combat attack at sea.

Rectified A-C System for Aircraft.....L. M. Cobb, W. L. Kershaw, Q. E. Erlandson . . . 95
Electricity Is an Integral Part of Agriculture.....W. J. Ridout, Jr. . . . 102
Sonar in Harbor Defense and Amphibious Landing..Elias Klein, Thomas F. Jones . . . 107
Feeder Voltage Regulator Application.....J. N. Gosinski, J. R. Oberholtzer . . . 115
Frequency Modulation Design Trends.....G. G. Young . . . 116
Planning a Large All-Hydroelectric System.....M. Ward, H. A. Smith . . . 117
Electronic Protective Relays.....
.....R. H. Macpherson, A. R. van C. Warrington, A. J. McConnell . . . 122
Precision Snap-Acting Switches.....A. L. Riche . . . 128
Methods of Stimulating Teaching in the Power Field.....E. W. Boehne . . . 135
Reversing Cycle of Modern Blooming Mills.....T. B. Montgomery, J. F. Sellers . . . 137
Ground Power for Aircraft.....John H. Blankenbuehler . . . 138
Radio Influence From High-Voltage Corona.....Gordon R. Slemon . . . 139
Measuring Conductor Resistance and Reactance.....E. H. Salter . . . 144
Coaxial Telephone-Television System Progress.....L. G. Abraham . . . 147
Rural Inductive Co-ordination Practices.....M. W. Rothpletz, H. S. Williams . . . 148
Emergency Control of System Loads.....
.....J. M. Comly, G. B. Kelley, J. E. McCormack, H. W. Phillips, T. W. Schroeder . . . 151
The Great Lakes Radiotelephone System.....R. H. Herrick . . . 152
Safety in Machine Tool Control.....D. K. Frost . . . 157
Evolution of Shovel and Dragline Control.....P. S. Stevens . . . 161
Interconnected System Load-Frequency Control.....H. M. Dimond, G. S. Lunge . . . 162
Electric Welding Conference Paper Digests.....
. . . 163

Miscellaneous Short Items:

Measuring Radioactive Isotopes, 106; Selective Sequence Electronic Calculator, 114; Testing With an Ultrasonic "Stethoscope," 121; A New Diffraction Microscope, 134; Electronic Reading Aid, 143: Electrical Essay, 145; Radio Detects Meteor Speed, 160

Institute Activities . . . 171
Of Current Interest . . . 180

Charles S. Rich
Editor

Edward E. Grazda
Associate Editor

F. A. Norris
Business Manager

J. S. Lopes
Advertising Director

VOLUME 68
NUMBER 2

Statements and opinions given in articles and papers appearing in *ELECTRICAL ENGINEERING* are the expressions of contributors, for which the Institute assumes no responsibility. ¶ Correspondence is invited on all controversial matters.

Published Monthly by the

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

Founded 1884

EVERETT S. LEE, President H. H. HENLINE, Secretary

PUBLICATION COMMITTEE: B. M. Jones, *chairman* J. M. Flanigen P. B. Garrett H. H. Henline
G. Ross Henninger R. K. Honaman D. E. Inman K. B. McEachron J. J. Orr B. R. Teare, Jr. C. F. Wagner

ELECTRICAL ENGINEERING: Copyright 1948 by the American Institute of Electrical Engineers; printed in the United States of America; indexed annually by the AIEE weekly and annually by *Engineering Index*, and monthly by *Industrial Arts Index*; abstracted monthly by *Science Abstracts* (London). Address changes must be received at AIEE headquarters, 33 West 39th Street, New York 18, N. Y., by the first of the month to be effective with the succeeding issue. Copies undelivered because of incorrect address cannot be replaced without charge.

HERE'S THE WIRE THAT CUTS YOUR PRODUCTION COSTS

PRICE DIFFERENTIALS PER 100 LB	
39	$ 76.00
40	95.65
41	130.00
42	180.00
43	245.00
44	335.00
45	500.00
46	1000.00

Base Price—8/16/48—$34.25

Belden
CELENAMEL ❀

❀ TRADEMARK REGISTERED

Belden
WIREMAKER FOR INDUSTRY

HIGHLIGHTS .....

Technical Conferences. Two more of the new AIEE technical-conference-type meetings were held recently with conspicuous success. The first of these, and the third meeting of this type, was the conference on electronic instrumentation in nucleonics and medicine held jointly with the Institute of Radio Engineers in New York, November 29–December 1. It was attended by more than 500 persons (*page 173*). This conference was followed, December 6–8, by the AIEE conference on electric welding which attracted some 436 persons to the Rackham Memorial Building in Detroit, Mich., where it was held (*page 172*).

President's Message. In this month's message to the membership, AIEE President E. S. Lee takes issue with the statement that "anyone can get into the AIEE." He particularly commends the work of the board of examiners and the committee on transfers in passing on applications for membership or transfer (*page 171*).

Digests. Most of the papers which are digested in this issue were presented at the AIEE Midwest general meeting in Milwaukee, Wis., October 18–22, 1948 (*pages 115, 116, 137, 138, 144, 147, 151, 161, 162*).

Electricity in Agriculture. As in industry, the present trend in agriculture is toward larger and fewer farms performing more and more of the processing operations often now performed away from the point of production. In line with this trend, the part played by electricity in farm production is assuming ever-increasing importance; the problem of the utilities will be to keep up with the new rural demand as it develops (*pages 102–06*).

Electric Welding Digests. Brief authors' digests are included in this issue for most of the papers presented at the recent AIEE conference on electric welding which was held in Detroit, Mich., December 6–8, 1948. These papers will not be published by the AIEE in any other form (*pages 163–70*).

Safety in Machine Tool Control. With the increase in complex machinery, safety features take on added significance. This article considers the subject not only from the standpoint of personal safety, but also from the standpoint of safeguarding the useful life and operation of the machine (*pages 157–60*).

Radiotelephone System. The Great Lakes shipping industry has been greatly benefited through the installation of a radiotelephone system. It was designed especially to fit their needs. Now, most of the 600 Lake vessels are equipped with radio transmitter-receiver sets which provide telephone-dial channel selection and allow use of the radiotelephone system in a manner similar to use of regular wire telephones (*pages 152–7*).

Inductive Co-ordination Practices. When power lines began to extend across rural America, many telephone lines serving these areas became practically unusable on account of electrical interference. Various means of correcting this situation were investigated. By properly co-ordinating power and communication systems lines on an inductive basis it has been possible to operate both services in close proximity (*pages 148–50*).

Radio-Interference Control. Studies have been made in the field of high-voltage power transmission to determine under what conditions radio-frequency propagation can be expected from corona. Experiments show that there are many influencing factors. With these facts, a beginning can be made in radio-interference control (*pages 139–43*).

All-Hydroelectric System. Many major factors must be considered in the planning of a large all-hydroelectric system such as the Southern Ontario System of The Hydro-Electric Power Commission of Ontario in Toronto, Canada. This system supplies power in the southern portion of the province, covering an area of approximately 47,000 square miles and having a population of approximately 3,500,000 throughout its 297 municipalities and rural areas. Particular consideration had to be given to determining the generating capacity requirements, the provision for reserve capacity, uses of surplus energy, and selection of sites for new plants (*pages 177–21*).

Snap-Acting Switches. Reductions in size, weight, and operating energy requirements have received a great deal of attention in the design of the new snap-acting switches. Such characteristics which distinguish them from other control devices give them unique usefulness. Growth in the variety and extent of their applications has been very rapid in the past 15 years (*pages 128–34*).

Electronic Protective Relays. With the increasing demand for greater speed, accuracy, and dependability, a need seems to be developing for electronic protective relays which appear, in laboratory test, to be more adequate than present electromagnetic protective relays. This article presents a report of progress in electronic relay developments and attempts to explain the present limited availability of such relays (*pages 122–8*).

Two Sonar Systems. One of the sonar systems described in this article was utilized by the Armed Forces to guard harbor entrances against sneak attacks by enemy submarines. The other, the ultrasonic underwater beacon, guided landing parties in amphibious operations to a preselected beachhead. Both equipments were characterized by the emission of ultrasonic signals from a relatively fixed underwater transducer (*pages 107–14*).

Rectified Aircraft System. A rectified a-c system for use in aircraft has several advantages over conventional d-c systems: it obviates the need for reverse-current cutouts and the problem of co-ordinating the trip characteristics of reverse-current cutout and reverse-current circuit breaker; it permits installation of larger capacity units on main engine accessory drive pads without the use of remote drive couplings; and it provides output at lower engine speeds (*pages 95–101*).

Belated Credit. A photograph comparing interference fringes formed by the green radiation of natural mercury with those formed by mercury 198 (an isotope) which was awarded first prize in the Second Photograph-in-Science Salon of the American Association for the Advancement of Science in September 1948, was published in the December issue (*EE, Dec '48, p 1223*). However, through an oversight, the caption did not indicate that the prize-winning photograph was taken in connection with a project at the National Bureau of Standards which involves basic measurement and nuclear physics, nor was credit given to Doctor W. F. Meggers who has spent considerable effort on this project.

News Index

Institute Activities.....171

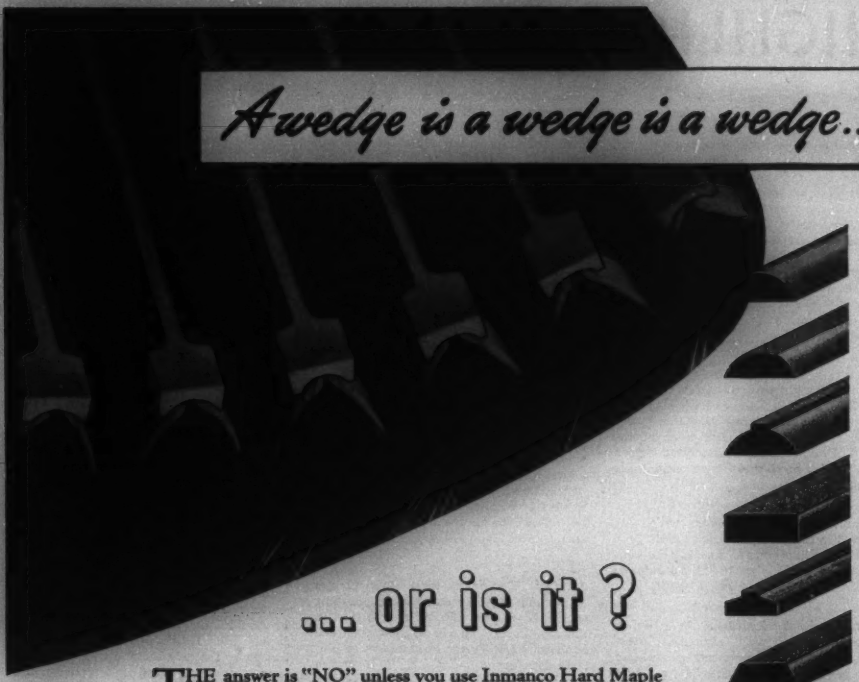
Message From President Lee.....171
Conference on Electric Welding.....172
Conference on Electronic Instrumentation.....173
AIEE *PROCEEDINGS* (how to order).....173
Future AIEE Meetings.....173
Personal Notes.....174
Obituary.....177
Membership.....178

Of Current Interest.....180

Electrical Manufacturers Reach Production, Sales Peak.....180
Research.....182
Education.....183
Future Meetings of Other Societies.....184
Other Societies.....184
Honors.....184
Letters to the Editor.....185
New Books.....186
Pamphlets.....186

Industrial Notes.....16A
Trade Literature.....26A
New Products.....44A

ELECTRICAL ENGINEERING. Published monthly by the American Institute of Electrical Engineers; publication office 20th & Northampton Streets, Easton, Pa. Editorial and advertising office: 500 Fifth Avenue, New York 18, N. Y. Subscription $12 per year plus extra postage charge to all countries to which the second-class postage rate does not apply; single copy $1.50. Entered as second-class matter at the Post Office, Easton, Pa., under the Act of Congress of March 3, 1879. Accepted for mailing as special postage rates provided for in Section 538, P. L. & R. Act of February 28, 1925. February 1949, Vol. 68, No. 2. Number of copies of this issue 37,300



THE answer is "NO" unless you use Inmanco Hard Maple Wood Wedges — accurate in shape and size, straight grain to give maximum mechanical strength without slivers, splinters or fractures in normal assembly operations.

Unless otherwise specified, Inmanco Wood Wedges are tumbled and paraffined to resist moisture and make assembly easy.

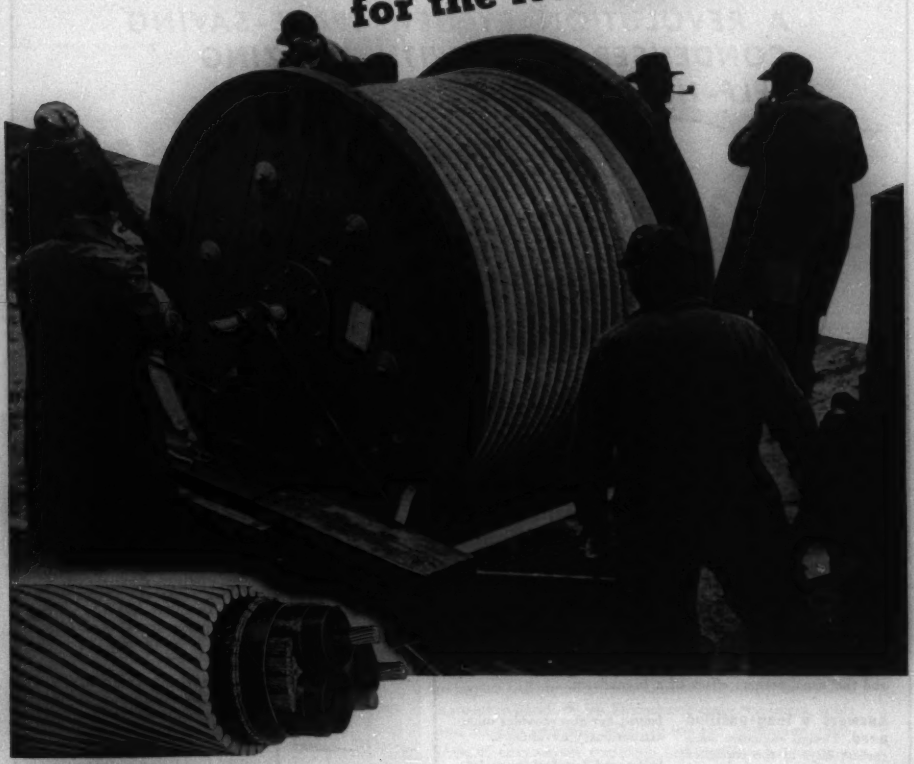
Inmanco Wood Wedges can be made to your specifications either in standard 30" lengths or special cut lengths.

Wedgie says:

"With 48 standard sizes in stock and over 250 special sizes in ten different styles, I can give you not only 'the new look' in wood wedges, but also a perfect fit."

WRITE FOR FREE DESCRIPTIVE BULLETIN AND SAMPLE CARD

overcoming an underwater problem for the Northern Pacific



▶ Spanning the St. Louis River, linking Duluth, Minn. to Superior, Wisconsin, swing bridges are operated by the Northern Pacific Railway, "Main Street of the Northwest." Heavy traffic depends upon their smooth electrical opening and closing. For these conditions the railroad wanted a submarine power cable of exceptionally long-lasting service life.

The choice was an Okonite submarine cable. The installation called for 3600 feet of 3-conductor cable. Conductors: Okoloy-coated for corrosion resistance, Semicon-taped to prevent internal corona cutting. Insulation: long-lived Okolite. Armor: Galvanized steel armor wire. O. D. of cable: 2.390". Weight: 5 lbs. per foot.

While moisture-resistance is, of course, an essential, perhaps the most important single factor in this cable's selection is the consistently stable electrical characteristics of Okolite high-voltage insulation even when submerged without an outer lead sheath.

Utilities, carriers, industrial plants use many kinds of Okonite cables — for wet locations, for hot spots, for extreme flexibility, for indoor and outdoor use above or below ground including direct burial. Write for Bulletin EG-1036. The Okonite Company, Passaic, N. J.

6979

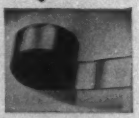
OKONITE insulated wires and cables

THE BEST CABLE IS YOUR BEST POLICY

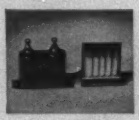
Announcing... METALLIZED PAPER

A REVOLUTIONARY NEW SPACE-SAVING CONDENSER PAPER WITH AMAZING SELF-HEALING QUALITIES.

SMITH'S New-type Metallized Condenser Paper not only reduces space factor by eliminating the use of electrodes, but gives longer life, higher dielectric strength, and ends forever the disastrous effects of breakdowns.



Metallized Paper



1 MFD—400 WVDC

4 MFD—150 WVDC

Capacitor samples courtesy Solar Manufacturing Corp., North Bergen, N.J.

NEW!!! NEW!!! Never before has anything like Smith Metallized Condenser Paper been offered the Electric and Electronic Industries.

It's here! Today . . . now . . . Smith Paper, Inc. makes available its new Metallized Condenser Paper that bids fair to revolutionize the entire electric and electronic field. Smith Metallized Condenser Paper makes possible the first one-layer condenser with an .0003" dielectric material. It also makes possible a 75% saving in space factor over most conventional capacitors. And because of its self-healing characteristics it almost completely eliminates the factor of conducting particles and the usual serious effect of a breakdown.

Answers a long-unfilled need. Design engineers since earliest days of the capacitor industry have sought capacitors that would provide higher capacities, smaller space factors, higher dielectric strength, longer life characteristics, and the elimination of breakdown causes. Since such improvements in design have been limited by the dielectric materials available, the introduction of Smith's Metallized Paper will prove a great boon towards the attainment of these special characteristics. This industry-sought paper not only permits 75% savings in space factor, but also provides other extraordinary advantages.

Increased insulation resistance. It has been found in the manufacture of metallized paper that by covering the base Kraft Condenser sheet with an extremely thin, continuous and uniform film of lacquer, a marked increase in insulation resistance is obtained. This lacquering causes an increase in the thickness of .00030 condenser paper of .03 - .05 mils; while the succeeding zinc coating operation causes an increase in thickness of 3 - 5 millionths of an inch.

Self-healing on breakdowns. Another of the outstanding properties of metallized paper is its capacity to self-heal on a breakdown. In other words, a capacitor wound with metallized paper may be brought to a breakdown voltage, but the effects of the breakdown are sufficient to cause a re-insulation around the breakdown area so that the capacitor is satisfactory for continued use. Numerous breakdowns do not appear to impair this self-healing characteristic. Smith Paper, by taking advantage of this property, is able to furnish a metallized paper devoid of particles which are conducting at the usual test voltages.

Automatically Controlled. Today equipment has been perfected for automatically controlling and continuously recording (where necessary) such properties as lacquer thickness and consistency, thickness of the metal layer, color and resistance of the metal layer, width of margin, etc. — all important characteristics of the product, the close control of which is essential for the best design and manufacture of metallized paper capacitors.

Complete facts available. All facts on Smith Metallized Condenser Paper as it applies to your industry may be had on request. Simply address Smith Paper, Inc., Lee, Massachusetts. There is no obligation.

SMITH PAPER, INC.

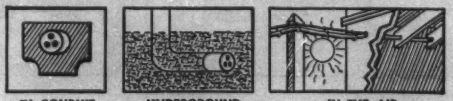
LEE, SMITH MASS.

Built for those TOUGH JOBS!

Small sizes or large . . . one, two or three conductors . . . moisture-resisting insulation . . . from 0 to 5,000 volts . . . Durasheath is built for rugged service:

Durasheath offers high tensile strength and resistance to impact and abrasion—*plus* extreme flexibility that makes it easier to handle. Also, Durasheath resists moisture, acids and alkalies generally found in the soil, eliminates problems of electrolysis, corrosion and extremes in temperature and is highly resistant to flame—making it possible to use a single type and size of cable in runs that are partly aerial, partly underground or in conduit.

For complete information, write for Publication C-27.



Anacondaloy®-coated copper conductors are insulated with a moisture-resisting synthetic rubber compound, bound with color-coded rubber-filled tape and enclosed in a tough, high mechanical strength, moisture and flame-resistant outer jacket of Neoprene. Conductors have the lasting protection of a solid block of synthetic rubber and Neoprene.

®Reg. U. S. Pat. Off.

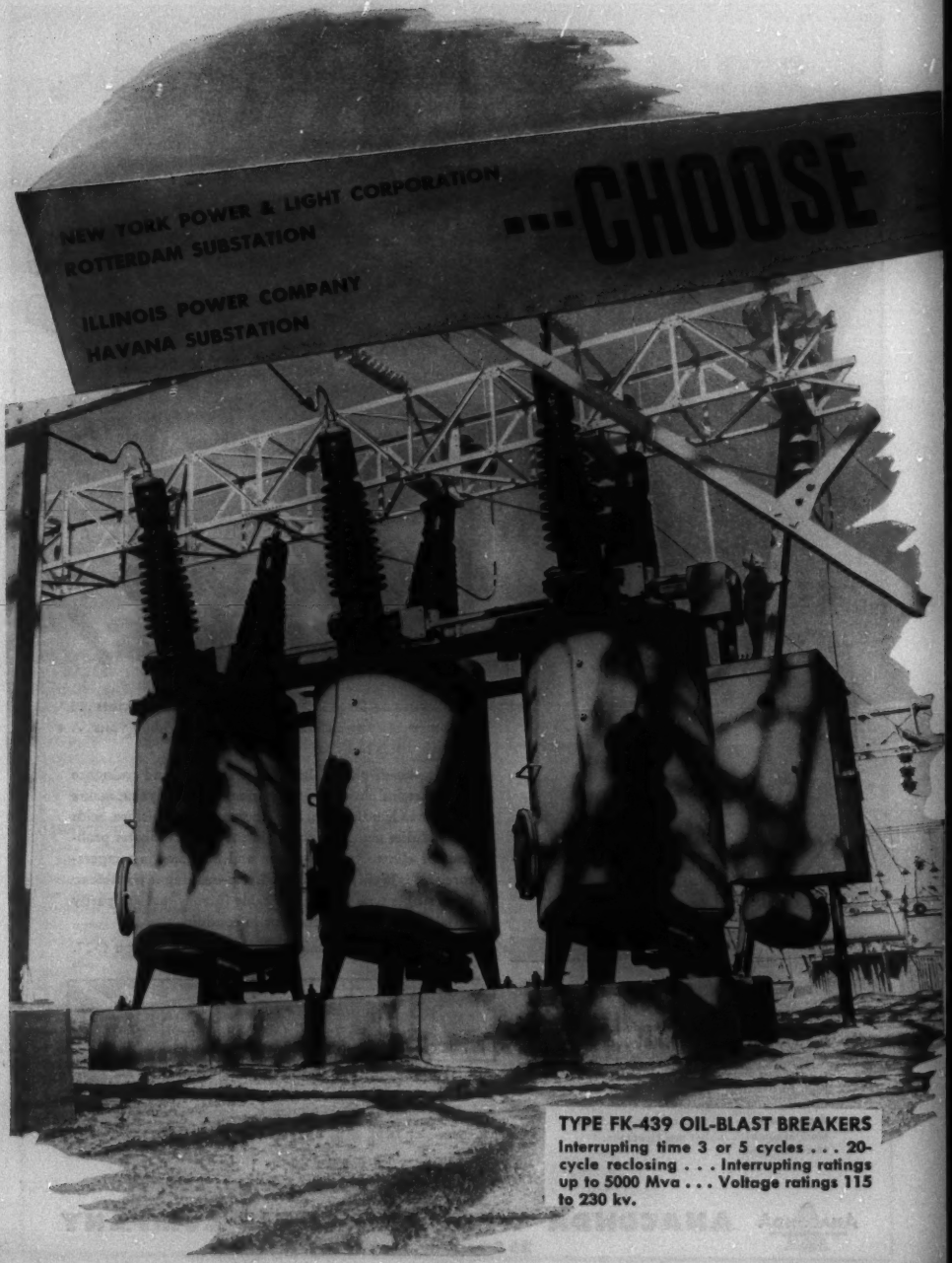
Durasheath

AN *Anaconda* PRODUCT

ANACONDA

ANACONDA WIRE AND CABLE COMPANY

25 Broadway, New York 4, N. Y.



TYPE FK-439 OIL-BLAST BREAKERS

Interrupting time 3 or 5 cycles . . . 20-cycle reclosing . . . Interrupting ratings up to 5000 Mva . . . Voltage ratings 115 to 230 kv.

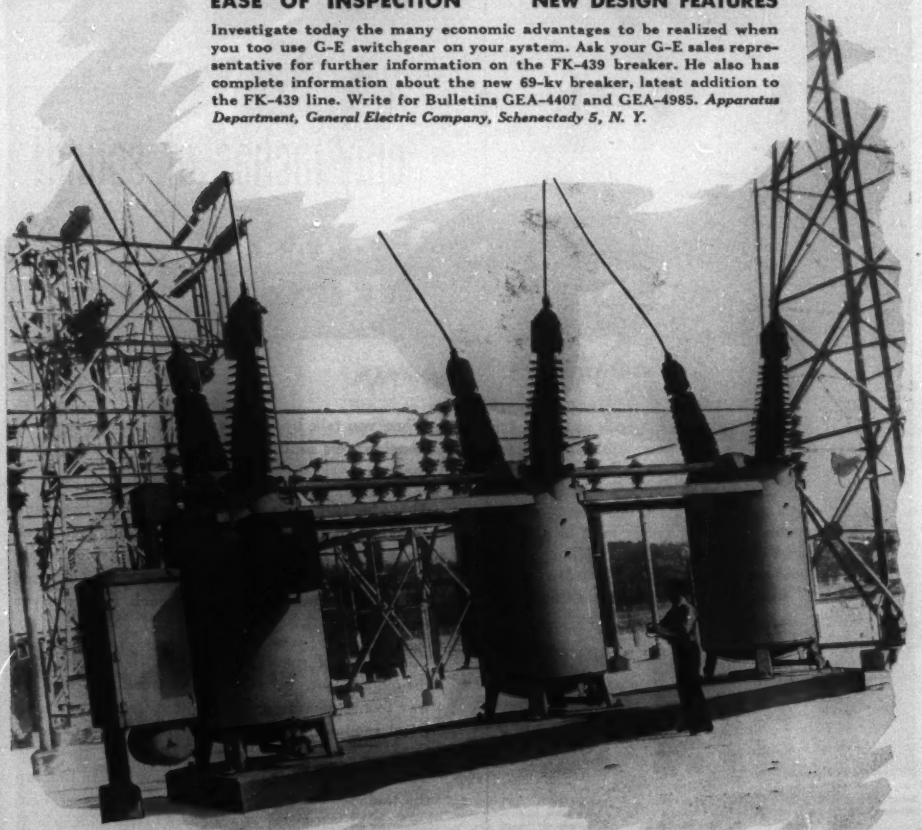
HIGH-VOLTAGE BREAKERS

FOR

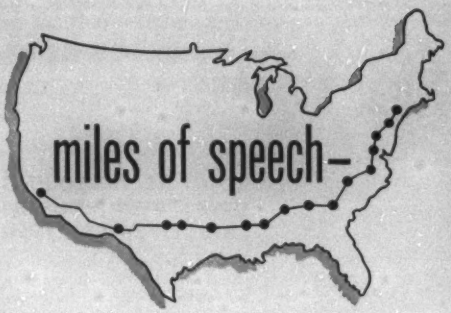
20-CYCLE RECLOSING
NEW SEALED BUSHINGS
EASE OF INSPECTION

3 OR 5 CYCLE HIGH-SPEED INTERRUPTION
NEW DESIGN FEATURES

Investigate today the many economic advantages to be realized when you too use G-E switchgear on your system. Ask your G-E sales representative for further information on the FK-439 breaker. He also has complete information about the new 69-kv breaker, latest addition to the FK-439 line. Write for Bulletins GEA-4407 and GEA-4985. *Apparatus Department, General Electric Company, Schenectady 5, N. Y.*



GENERAL ELECTRIC



only inches of sound!

When you talk by telephone, far or near, the actual sound travels much less than when you talk across the room!

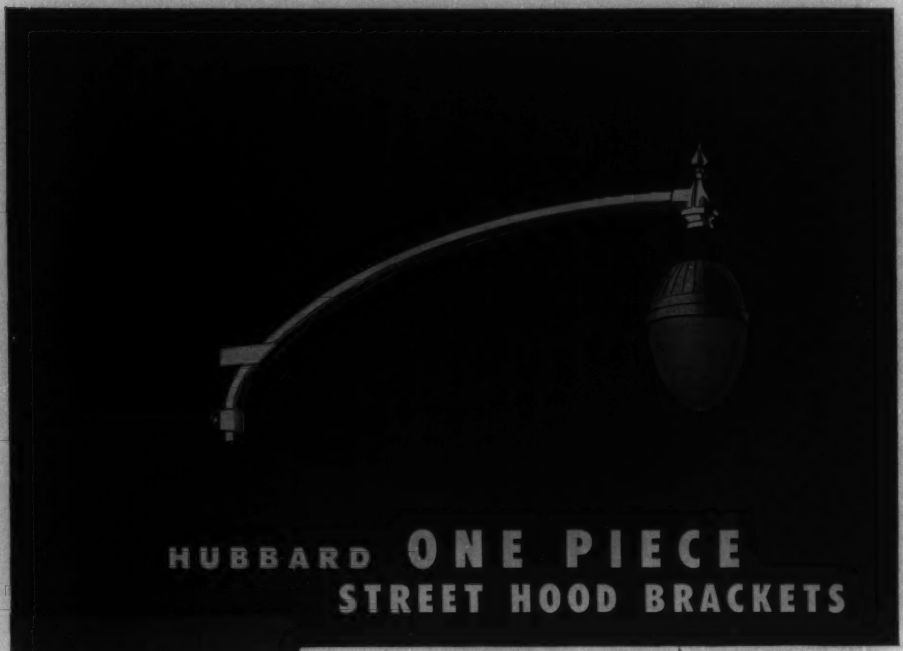
That's because the telephone system carries not sound itself but an electrical facsimile of sound. When you speak into a telephone transmitter your voice is converted into electrical vibrations which are not changed back into sound until they reach the receiver diaphragm.

Conversion of sound into its electrical equivalent, through the invention of the telephone, opened the way to the measurement of sound by accurate electrical methods. In developing means to make the telephone talk farther and sound clearer, the scientists of Bell Telephone Laboratories had to develop the tools for sound-wave analysis and measurement.

The condenser microphone, the wave filter, the amplifier — each the product of telephone research — have helped to reveal the structure of sound as never before. Each has helped to build the world's finest telephone system.

BELL TELEPHONE LABORATORIES

EXPLORING AND INVENTING, DEVISING AND PERFECTING, FOR CONTINUED IMPROVEMENTS AND ECONOMIES IN TELEPHONE SERVICE.



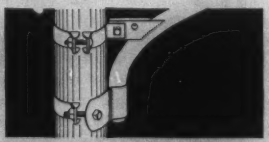
HUBBARD ONE PIECE STREET HOOD BRACKETS

Installation on Steel Pole (See diagram)

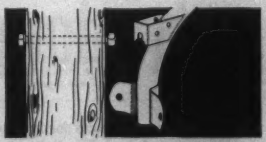
ANOTHER FIRST– Hubbard, One Piece, Upsweep Brackets are a development in Street Lighting made necessary partly by the requirement for higher mounting of Luminaires, without setting new poles and without "wasting" pole space for bracket supports, and partly by a demand for greater simplicity and efficiency plus low cost. They can be mounted at the pole top if desired.

Furnished in lengths from three to six feet, these arms are all "one piece" design requiring no pole plates, braces, brace clips, insulator bushings or other fittings. They can be attached by one man. There are no sharp bends or other obstructions to hinder internal wiring. Complete data is forthcoming on these and greater lengths. Write for your copy.

Installation on Wood Pole



Design of the Hubbard "One Piece" Street Lighting Bracket allows use on wood or steel poles merely by the application of pole bands. No change in design of the arm.



The new, exclusively Hubbard, Keyhole type (Patent applied for) of attachment above permits installation by one man.

HUBBARD AND COMPANY

PITTSBURGH CHICAGO OAKLAND, CALIF.

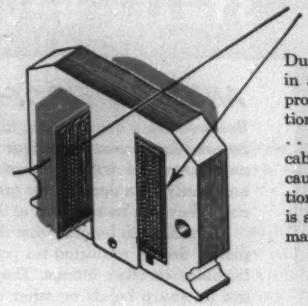
First all-new watt-hour meter in 50 years

GENERAL ELECTRIC CO. says "The I-50 is the first all-new watt-hour meter in 50 years—new in conception, design, operation, and use of modern materials and techniques. It has greater sustained accuracy, longer life."

For greater insulation strength, reliability and secure positioning, the potential coil is molded to the electromagnet core with Du Pont polythene. This plastic combines high dielectric strength with low moisture-absorption.

employs Du Pont POLYTHENE

G. E.'s new potential coil stands about 15 kv under impulse, and 10 kv under 60-cycle breakdown. The polythene insulation stands up under humidity, sunlight and increased temperatures. It's non-corrosive, resists tracking (90 seconds minimum by ASTM test), permits better-insulated leads and neater mechanical design.



Du Pont polythene serves today in a myriad of better electrical products. Wire and cable insulation . . . insulating films and tapes . . . insulating discs for coaxial cables—those are just a few. Because of its remarkable combination of good properties, polythene is steadily replacing many other materials for electrical work.

for extra-long life of potential coil

Look to polythene for improving *your* products! It's light, tough, strong; resists chemicals and moisture. It has high dielectric strength, a low power factor and is stable over years of service. Polythene molding powders are available in colors . . . may be injection- or compression-molded or extruded as sheeting, tubing or wire-covering.

DU PONT
REG. U.S. PAT. OFF.
Plastics
BETTER THINGS FOR BETTER LIVING
. . . THROUGH CHEMISTRY

Write today for the facts on versatile Du Pont polythene! We'll send properties data plus data on how others have used it in making a host of improved products of many different types. Just write: E. I. du Pont de Nemours & Co. (Inc.), Plastics Department, Room 162, Arlington, N. J.

Tune in to Du Pont "Cavalcade of America" Monday nights—NBC coast to coast

A Rectified A-C Electric System for Aircraft

L. M. COBB
ASSOCIATE AIEE

W. L. KERSHAW

Q. E. ERLANDSON

The use of electricity as a service component of aircraft has progressed to a degree which taxes the available generator drive capacity on main engines, a deficiency which has resulted in material improvements in generator design. To provide adequate generator capacity on one recently developed airplane, it was necessary to use a relatively unconventional system employing main-engine-driven low-voltage alternators and selenium rectifiers.

THE TYPE of generating system selected for an airplane must be based on an analysis of the generating system requirements and installation limitations, and is not governed by any established rules. A-c and d-c generating systems for aircraft, and their relative merits, have been the subjects of numerous authors. Very few airplanes have been equipped with a rectified a-c generating system and it is believed that the system presented is the largest installation of its type.

SELECTION OF SYSTEM

With the development of larger reciprocating aircraft engines during and since the war, a relatively small increase in accessory pad capacity for generating equipment has been provided in the face of rapidly increasing electric power requirements. In the fall of 1944 a 2-engine airplane was designed having electric loads well in excess of many of its 4-engine predecessors. Four generator pads were available, but with two pads on each engine, the loss of either engine meant the loss of half the generating equipment.

The anticipated electric power requirement was approximately 1,000 amperes direct current at 28 volts with peak demands as high as 3,200 amperes.

The four pads available were *AND-10002* type *1A* having the following characteristics: allowed overhung moment, 350 pound-inches; continuous torque output, 600 pound-inches; allowed weight, 50 pounds. In addition, each engine had a third accessory pad on the engine centerline. This pad would provide 1,500 pound-inches torque, but its use would have necessitated a remote drive at a penalty in weight, installation difficulties, and maintenance, because the allowed overhung moment was limited to 75 pound-inches.

Before the final selection was made, the following systems had been studied: a conventional low-voltage d-c system; a d-c system supported in part or supplied in toto by a gasoline-driven auxiliary power unit; a combination d-c and a-c system; and the rectified a-c system which finally was installed. A straight d-c system powered by engine-driven generators without assistance from an auxiliary power unit required a minimum of four 400-ampere generators to meet the airplane's power requirements. Although 400-ampere d-c generators were in the development stage, the largest generators then available had a capacity of only 300 amperes. Since the weight and overhung moment of the 300-ampere machines approached the engine limits, it seemed doubtful that a 400-ampere generator could be designed to meet the engine manufacturer's restrictions. Inasmuch as the weight comparison, Table I, between the two systems showed a negligible weight difference, no further consideration was given to 400-ampere d-c machines. Available auxiliary power units were of small capacity and would have been impractical as primary power sources. The most promising combination a-c–d-c systems were eliminated for one or more of the following reasons: space limitations in the nacelle prohibited the use of a constant speed drive; additional generator pads were needed to provide spare capacity requirements; the belief prevalent at the time of the design of the airplane that satisfactory operation of a variety of electronic gear could not be obtained from a single a-c source. The rectified a-c system finally was selected as having the most desirable features.

The rectified a-c system as shown in Figure 1 consists of four low-voltage 3-phase engine-driven alternators, each connected to a full wave rectifier for converting the entire alternator output to 28-volt direct current. The four units and two 34-ampere-hour batteries are connected to a common bus. Carbon-pile regulators are used to maintain nominally constant voltage between the positive rectifier terminal of each unit and ground. The nominal rating of

Table I. Weight Comparison

Conventional D-C System Versus Rectified A-C System

	Four Alternator-Rectifier Units in Pounds (Rating 1,600 Amps)	Four 400-Ampere D-C Generator in Pounds (Rating 1,600 Amps)
Alternator (4)	168.4	
Generator (4)		260.0
Regulator (4)	25.2	10.0
Reverse-current circuit breaker (4)	5.0	5.0
Generator contactor (4)	9.2	
Firewall disconnects (4)	20.4	18.2
Wire*	104.6	96.1
Switches, indicator lights, resistors	3.2	1.7
Ammeters, voltmeters, shunts	14.2	14.2
Installation weights	29.7	4.5
Rectifiers 24.0		
Miscellaneous equipment 5.7	4.5	
Rectifiers (4)	50.0	
Reverse-current cutout (4)		14.0
Total	429.9	423.7

* Note: Based on the use of aluminum wire where practical.

Full text of paper 48-229, "A Rectified A-C Electric System," recommended by the AIEE air transportation committee and approved by the AIEE technical program committee for presentation at the AIEE Middle Eastern District meeting, Washington, D. C., October 5-7, 1948. Not scheduled for publication in AIEE *TRANSACTIONS*.

L. M. Cobb, W. L. Kershaw, and Q. E. Erlandson all are with the electrical design section, The Glenn L. Martin Company, Baltimore, Md.

The authors acknowledge the assistance of the electrical design section and the electrical laboratory during the preparation of this article.

the system is 1,600 amperes direct current at 28 volts. Suitable instruments, controls, and circuit protection devices are provided.

Alternator. The alternator is a 30-volt 16-kva delta-connected 12-pole 3-phase machine with a speed range of 4,000 to 8,000 rpm.[1] The torque required is 350 pound-inches at rated load at 4,000-rpm alternator speed. The weight is 42.1 pounds and the overhung moment is 195 pound-inches. At rated load, cooling air at a maximum temperature of 40 degrees centigrade is required at a pressure equivalent to six inches of water, total head. The alternator is much smaller than the *AND* standard generator envelope and is designed for mounting on a standard accessory pad, by means of a quick disconnect type mounting flange, as shown in Figure 2.

Rectifier. The rectifier is a 3-phase full-wave bridge-type assembly of 96 selenium plates.[1] The manufacturer's original rating of the rectifier was 200 amperes at 28 volts direct current, but after tests had been conducted by the Army, the rating was increased to 300 amperes. Using the same rectifier with a redesigned duct, as shown in Figure 3, laboratory data indicate that cooling airflow is increased sufficiently to permit operation within the manufacturer's temperature rise limits when carrying 400 amperes with cooling air equivalent to six inches of water total pressure head. Two rectifiers are mounted in the leading edge of each wing, behind the propeller, in the zone of maximum activity. The propeller provides cooling air for ground operation. A screen installed in each duct aft of the rectifier prevents the entrance of foreign matter. Thermocouples were installed in the rectifiers to indicate plate temperatures during cooling tests. The installed weight of each rectifier is 18 pounds.

Regulator. The regulator is a conventional carbon pile unit[2] equipped with a cooling fan to increase the rating to 175 watts. The resistance limits of the regulator stack are 0.35 ohm minimum and 25 ohms maximum. The regulator is equipped with pin jacks as a convenience for adjustment and is provided with a quick disconnect receptacle for all connections. The regulator assembly weighs 6.3 pounds.

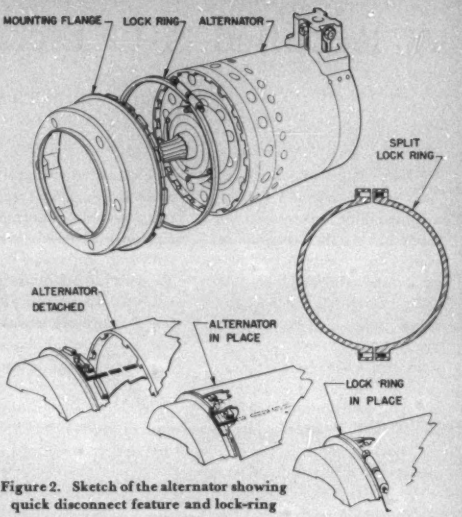


Figure 2. Sketch of the alternator showing quick disconnect feature and lock-ring

Protective Units. Obviously, the rectifier serves as reverse-current protection for the alternator and the leads between the alternator and rectifier. An emergency field switch is provided to permit opening the alternator field circuit to de-energize the alternator in the event of a fault on the a-c side of the rectifier.

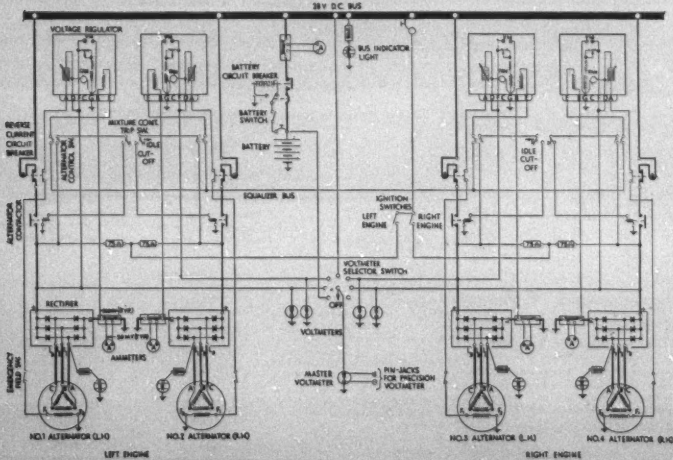


Figure 1. Schematic wiring diagram of rectified a-c electric system

A reverse-current circuit breaker, installed adjacent to the bus, provides reverse-current protection for the rectifier and leads between the rectifier and the bus. Auxiliary contacts of the reverse-current circuit breaker serve to open the alternator field circuit. The system is not subject to the instantaneous reverse-current surges, hence the nuisance trips which were experienced in the first reverse-current circuit-breaker installations in conventional d-c systems are avoided.

A conventional d-c system requires the use of reverse-current cutouts to prevent the flow of reverse current between paralleled generators having different terminal volt-

ages. In the past, considerable difficulty has been experienced in attempting to coordinate the tripping characteristics of a reverse-current circuit breaker and a reverse-current cutout; but on this installation no such problem exists because the rectifier obviates the need for reverse-current cutouts.

Control Devices. A contactor installed adjacent to, and on the rectifier side of, the reverse-current circuit breaker is

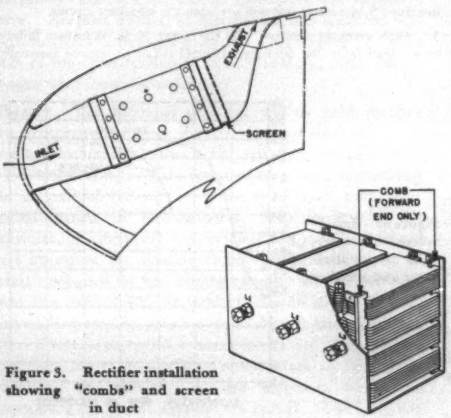


Figure 3. Rectifier installation showing "combs" and screen in duct

provided for normal control of the alternator. The contactor can be opened by either the alternator control switch on the distribution panel or by a switch coincidentally operated by the mixture control for the engine as shown in Figure 1. With this arrangement the alternator can be controlled manually by the flight engineer, or automatically by the pilot. The alternator is disconnected from the bus when the mixture control is in the idle cutoff position. A second pole of the alternator control switch is used to break the equalizer bus connection of the alternator to prevent a decrease in system voltage when the alternator is not operating.[3]

Instrumentation. The instrumentation is of the type conventionally used in a d-c generating system, including a 500-millivolt shunt which is installed in the d-c ground circuit of the rectifier to provide one-half volt equalizer potential at rated load. The shunt is tapped to provide 50 millivolts at 600 amperes for the ammeter. In addition to individual d-c voltmeters indicating the regulating point voltage of each machine, a master voltmeter and selector switch facilitate accurate voltage readings at each rectifier.

Batteries. Two *AN 3150* 34-ampere-hour 24-volt batteries are installed to provide initial field excitation and to stiffen the system on surge loads.

SYSTEM OPERATION

Energizing the System. In preparation for starting the engines and operating the electric system, the d-c bus must be energized by the airplane's batteries or an external power supply. Extra contacts of the main engine ignition switches are used to provide approximately one-quarter ampere "tickler" current from the bus for the field of each alternator when ignition is turned on. This current is required to initiate normal voltage build-up at low alternator speed. At low alternator speeds, without the assistance of the "tickler" current, the alternator residual voltage is insufficient to force current through the rectifier for reinforcing the residual field and therefore build-up cannot be accomplished. At very high speed, build-up is possible without "tickler" current, but is unpredictable because of the variable nature of the residual field. In that case, build-up, if it occurs, will be extremely rapid and the regulator will be unable to limit input voltage to the rectifier to a value below that which will cause rectifier flashover. Repeated flashovers will cause destruction of the rectifier.

After the engine has been started and alternator speed has increased gradually to approximately 2,200 rpm, voltage build-up occurs. At this speed, which is within the engine idling range, rectifier output voltage stabilizes at approximately 26 volts at no-load without overshoot. The complete build-up cycle requires one-quarter second as shown in Figure 4. As alternator speed is increased further, generated voltage rises to the normal operating value. If the alternator is accelerated rapidly from a speed below 2,200 rpm to a high speed, build-up begins at 2,200 rpm and voltage stabilizes within one-quarter second. The maximum voltage during build-up is a function of the rate of acceleration of the alternator. As shown in Figure 5, the maximum alternating voltage during the build-up cycle for an acceleration from 1,500 to 4,000 rpm in one second is approximately 25 volts rms. Rectifier flashover will not occur if the alternating voltage is limited to a maximum of 36 volts rms.

If the control switch is in the "on" position, the contactor will close when the rectifier output exceeds 18 volts, and will remain closed as long as the circuit to the contactor coil is complete and bus potential exceeds contactor drop-out

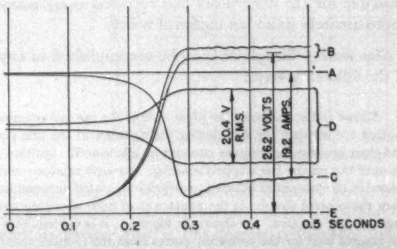


Figure 4. Typical oscillogram of voltage build-up with alternator running at constant speed (2,200 rpm)

A—Zero field amperes
B—Direct volts at regulating point; ripple envelope shown
C—Field amperes
D—Envelope alternating volts
E—Zero direct volts at regulating point

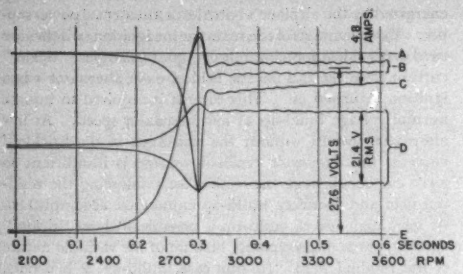


Figure 5. Typical oscillogram of voltage build-up with alternator accelerated rapidly

A—Zero field amperes
B—Direct volts at regulating point; ripple envelope shown
C—Field amperes
D—Envelope alternating volts
E—Zero direct volts at regulating point

voltage. The rectifier, performing the function of a valve, permits parallel operation of all four alternators, even though one or more are not carrying load, as could be experienced when the system is operating at very light load or one engine is idling while the second engine is running at a higher speed.

Normal Operation. Normal ground operation is limited to a minimum engine speed of 800 rpm, which corresponds to an alternator speed of 2,400 rpm. At this speed the propeller provides ram air pressure equivalent to one or two inches of water for cooling each alternator and rectifier. Each alternator-rectifier set will deliver a maximum of 75 amperes direct current at 26 volts as shown in Figure 6, and 100 amperes at 24 volts.

During takeoff maximum alternator speed is 8,100 rpm. During normal cruise alternator speed is maintained at approximately 6,000 rpm. At these speeds each machine will deliver a minimum of 400 amperes at rated voltage.

At minimum cruising speed, the cooling air pressure available for the alternators and rectifiers is equivalent to approximately six to ten inches of water.

Shut down. Shutdown may be accomplished in any one of the following ways:

1. *Normal system shutdown after flight.* As is the normal practice, the engines are stopped by first closing the throttles to the idle position and then placing the mixture controls in idle cutoff. Ignition is left on until the engine has stopped rotating. As each mixture control is placed in the idle cutoff position, a switch is operated automatically to open the control circuits of the contactors of both alternators on the engine being stopped. As shown in Figure 1, it is evident that since the control feed for the contactor comes from the rectifier side of the contactor, reclosing the alternator control switch or the idle cutoff switch will not cause the contactor to reclose unless the engine is running and rectifier output voltage is greater than contactor pick-up voltage. After stopping the engines, the alternator control switches normally are opened; however, if the switches are left closed inadvertently, system operation is not affected. Field "tickler" current drain is interrupted when ignition is turned off.

2. *Single engine shutdown.* In the event of an engine failure, which may or may not be followed by returning the mixture control to idle cutoff, the following conditions will exist until the alternator control switches are opened:

(a). The contactors of the affected alternators will remain closed.
(b). The affected alternators will draw full field current.
(c). The equalizer circuit will remain closed and will reduce system voltage.[3]

Upon opening the alternator control switch, the contactor coil circuit is broken, disconnecting the alternator from the bus and interrupting the main circuit from the bus to the alternator field. A second pole on the alternator control switch breaks the equalizer circuit.

Placing the mixture control in idle cutoff will open the contactor and interrupt field current but will not open the equalizer circuit.

3. *Single alternator shutdown.* In the event of an alternator failure or a-c lead fault, the alternator control switch is opened manually to disconnect the unit from the bus and open the equalizer circuit. The emergency field switch is opened to de-energize the alternator. The emergency field switch must not be reclosed while the alternator is running because of the resulting voltage overshoot on build-up and possible rectifier damage.

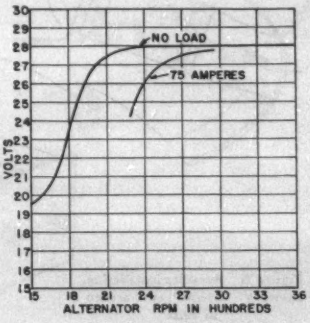


Figure 6. Speed–voltage characteristics of one alternator and rectifier

4. *Rectifier or rectifier lead fault isolation.* In the event of a rectifier failure or a lead fault between the rectifier and bus, the reverse-current circuit breaker will trip on any fault current in excess of 400 amperes, and will interrupt both the fault current and the alternator field circuit. The alternator control switch should be opened to break the equalizer circuit. The reverse-current circuit breaker should not be reset while the alternator is running.

Figure 7. Laboratory setup showing alternators mounted on the vari-drives, rectifiers, equalizer shunts, ground bus, and cooling fans and ducts

PERFORMANCE CHARACTERISTICS

A laboratory study was made of the complete generating system to observe performance under anticipated normal and abnormal conditions and any tendencies toward instability. The study also served as a means for establishing optimum circuit resistances, and to determine the presence of "sneak" circuits which could lead to faulty operation. Actual airplane equipment was used including developed wire lengths and gauges. Three 50-horsepower and one 15-horsepower variable speed electric drive were used as motive power. Airblast cooling of alternators and rectifiers was simulated with centrifugal blowers. (See Figure 7.) As a result of the investigation in the laboratory, some design changes were found desirable.

Rectifier. The foremost problem was to hold rectifier plate temperature below the 169-degree-Fahrenheit limit fixed by the manufacturer. The rectifiers are used with 16-kva alternators, and are required to carry a normal full load current of 400 amperes, one-third more than their nominal rating of 300 amperes. Replacement of the enclosures furnished with the rectifiers by specially designed ducts improved the cooling characteristics sufficiently to permit operation at the higher rating. Heat runs were made at a load of 400 amperes at 28 volts direct current. With cooling air ram pressure equivalent to three inches of water, a stabilized rectifier temperature rise of 63 degrees Fahrenheit above an ambient temperature of 76 degrees Fahrenheit was observed; at ten inches of water, the temperature rise was 28 degrees Fahrenheit. The foregoing data indicate that satisfactory cooling can be obtained at a load of 400 amperes direct current with ram air pressure equivalent to three inches of water in ambients as high as 100 degrees Fahrenheit. For safety reasons, cooling air ram pressure was maintained at ten inches of water throughout the laboratory tests of the system.

Aging reduces the over-all efficiency of the rectifiers.[4,1] This efficiency reduction necessitates the application of higher alternating voltage to maintain 28 volts direct current and consequently may result in flashover of the rectifying layer if breakdown potential is reached. After a period of approximately 1,500 hours, the amount of efficiency reduction will determine the life of the rectifier.

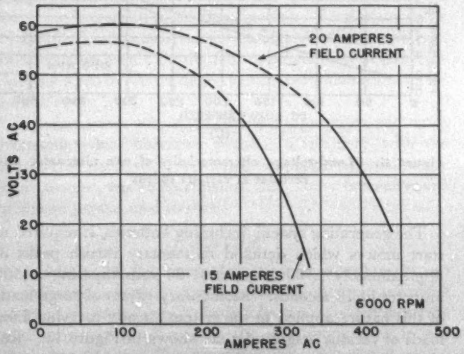


Figure 8. Load-voltage characteristics of one alternator with fixed excitation

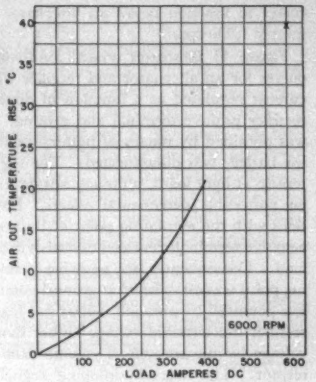


Figure 9. Alternator load-temperature characteristics at 6,000 rpm with cooling air pressure equivalent to six inches of water

Alternator. Load-voltage characteristics of an alternator with fixed excitation are shown in Figure 8.

Lack of laboratory facilities has prevented alternator efficiency tests, but the alternator manufacturer indicates an efficiency of about 85 per cent at full load resulting in an over-all efficiency of the alternator-rectifier combination of about 72 per cent.

Figure 9 shows alternator stabilized outlet air temperature rise expressed in terms of d-c output within the rating of the machine and an additional experimental point is shown at 600 amperes load. Inasmuch as the maximum safe outlet air temperature is 100 degrees centigrade, the test data indicate that the cooling air requirement of six inches of water equivalent pressure at 40 degrees centigrade for rated load is conservative.

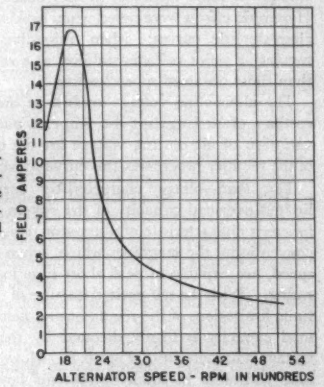


Figure 10. Speed-field current characteristic of one alternator and rectifier at no load

System. The speed-voltage characteristics of the system, Figure 6, establishes essentially flat regulator response at 28 volts no-load above 2,400 rpm. The speed-field current characteristic at no-load, Figure 10, indicates the regulator

ceases to function below an alternator speed of approximately 1,950 rpm.

Figure 11 illustrates typical load-voltage characteristic curves for an alternator and rectifier with alternator-field current regulated as a function of direct voltage between rectifier positive terminal and ground. Voltage buildup was obtained by means of battery excitation, after which the battery was disconnected. The slightly rising characteristic at light loads, although not desirable, has produced no noticeable detrimental effects. Preliminary observations with the regulating point at the rectifier positive and negative terminals revealed excessive drop at the bus at full load. Consequently, the negative terminal of the regulating point was established at ground potential increasing the bus potential by one-half volt at full load and establishing rectifier d-c terminal voltage higher than regulating point voltage by the amount of voltage drop in the equalizing resistor. The over-all drooping regulator characteristic, supplemented by a three-quarter volt feeder drop between rectifier and bus, provides unusually good load division at all operating speeds. With voltage regulators and rectifiers in good condition, loads of all magnitudes divide between the four machines with a maximum current spread of not more than 20 amperes.

The initial response to load changes was observed to be relatively fast; however, a noticeable sluggishness was observed in readjustment to a final steady voltage value, as is characteristic of most carbon pile regulators. Some final readjustment periods were observed to be of 30-second duration, during which time the regulating point voltage would change in some instances in the order of one-half volt. Hysteretic effects were noted when making the load-voltage characteristic curves; when unloading the system, the regulating point voltages stabilize at a value slightly higher than those obtained when loading.

The alternating voltage applied at the terminals of the rectifier plotted against d-c amperes output indicates the variation of alternating voltage for d-c output. As aging of the rectifier progresses, this curve moves upward.

The load-voltage characteristic curves indicate the limited overload capacity of the system resulting from an inherent characteristic of alternator design as contrasted to conventional d-c machines which, when operating at high speed, are capable of peak short time loads of three times rating. With the self-excited features of this system and the finite limitations of the regulator and field circuit, the overload capacity is firmly dictated by the alternator load-voltage characteristic, Figure 8. However, reduction of load resistance in small decrements beyond the point of maximum load current, corresponding to conditions as represented by the positive slope portion of the curve, does not precipitate collapse of voltage; when the load is removed, the system recovers to normal operation. It has been found that the system will carry overloads of greater magnitude when load suddenly is applied than when it is added in small increments. This increased overload capacity is indicated by the dotted portion of the load-voltage characteristic curves, Figure 11*B*. At a load in excess of 800 amperes at rated voltage per machine, rectifier terminal voltage decreases to zero and fails to recover when the load is removed.

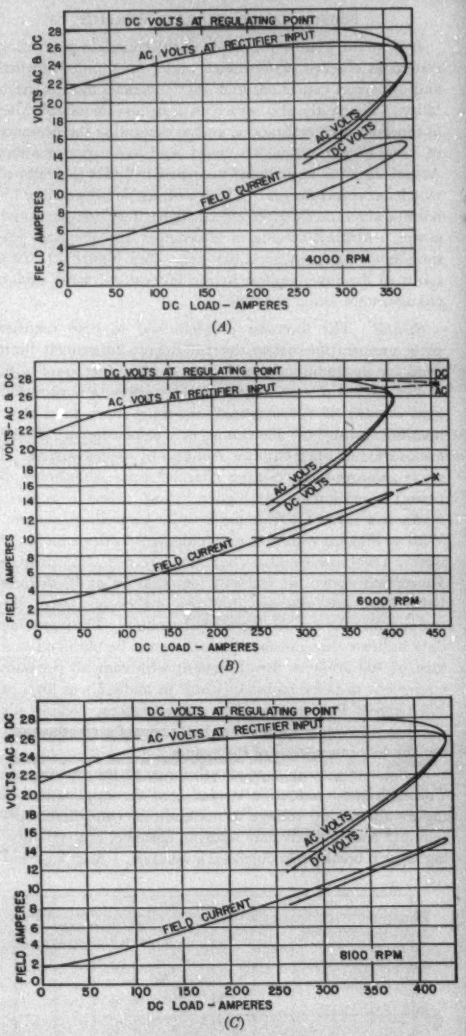


Figure 11. Load-voltage characteristics of one alternator and rectifier at various speeds

The generating system, including batteries, is required to start motors which demand momentary inrush peaks of approximately 1,700 amperes at 28 volts tapering to 500 amperes in 10 seconds. Momentary effects of surge loads of this nature applied to the system already carrying fixed loads of various magnitudes are shown in Figure 12. Recovery to normal system voltage is experienced as the motor approaches running speed.

With heavy short circuits applied to the bus, the system without batteries is not capable of sustaining voltage and the reduced voltage at the d-c terminals results in lower field voltage with the cumulative effect being system collapse; with batteries connected, heavy bus short circuits cause the system to cycle. The short circuit causes the rectifier voltage to drop below the drop-out value of the alternator control relay; the sudden opening of the load circuit with full field results in rapid voltage build-up which causes 35 to 45 volts alternating current at the alternator terminals and results in rupture of the rectifying layer. After the sudden voltage build-up, the relay recloses on the short circuit and the cycle is repeated. This inability of the alternator to sustain voltage during short circuits is an unhealthy condition that damages the rectifiers and does not contribute to the clearance of faults. It is believed that this weakness can be overcome by special circuits now under test which have been developed to maintain field voltage under short-circuit conditions.

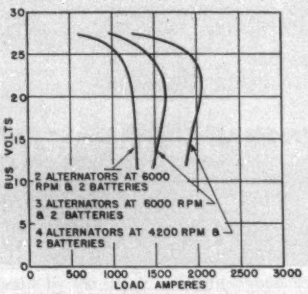


Figure 12. System load-voltage characteristics under surge load conditions

In contrast to bus short circuits, a short circuit occurring between the reverse-current circuit breaker and the rectifier is cleared by the reverse-current circuit breaker in about 25 milliseconds.

The rectifiers used in the laboratory tests suffered innumerable flashovers, but, by virtue of the self-healing characteristics of the selenium plates, the only serious effects were a reduction in rectifying capacity. Each plate in the rectifier is fused to protect the system against current follow-up after flashover. Of the four rectifiers used in the tests, only one aged or was damaged to a degree which necessitated replacement.

The alternator output contains a fifth, seventh, and ninth harmonic when operating without a rectifier; with the rectifier in the system, the ripple voltage is approximately four per cent, but no detrimental effects have been observed with equipment used to date.

SERVICE

A failure of the alternator bayonet attachment was experienced, after comparatively little flight time, as a result of engine vibration which caused loosening of the lock ring and subsequent shearing of the positioning pins in the mounting flange. The alternator manufacturer remedied the condition by substituting an improved split lock ring with heavier screws at diametrically opposite points, as shown in Figure 2, that permitted the lock ring to be drawn tighter. No further failures have occurred.

Several failures in the front stack of the rectifiers have occurred in dives and at high air-speed. It is believed that the cause for these failures was aerodynamic instability of the plates which are supported only at two points. At high speed the plates flutter, excited by the air blast, and eventually fail near the support. This installation deficiency was corrected by inserting a "comb" in the leading edge of the forward stack to hold the plates rigidly in place, (Figure 3). No further failures have been experienced.

CONCLUSIONS

The system has been operated for a limited number of hours, but for a sufficient time to make estimates on the life expectancy of the system components.

It is expected that alternator life will equal or exceed that of present day d-c aircraft generators. Brush life probably will be very good because of the relatively low current density and the longer life normally expected of brushes used with slip rings.

Based on laboratory life tests, the life of a rectifier in service is predicted to be 1,500 hours. Efficiency checks will be made at every major overhaul of the airplane to determine the exact life and replacement period.

It has been discovered recently that regulator stack life is not equal to the performance experienced in conventional d-c systems. The reason for this relatively short life may be attributed to the high wattage rating of the regulator or the repeated high shock loads which it handles in normal service. Tests are now underway to determine and, if possible, eliminate the difficulty.

With the improvement in overload and short-circuit characteristics resulting from the new circuits under development to prevent collapse of field voltage, it is believed that this sytem will serve as an adequate replacement for a conventional d-c generator system while avoiding the difficulties common in the application of large and heavy generators to the accessory cases of engines which never have been adequately designed for such loads. The rectified a-c system possesses further advantages in the matter of output at low engine speeds as compared with any 400-ampere d-c generators now available within the *AND* standard generator envelope dimensions.

Experiments conducted with greater than normal field excitation indicate that there is a good possibility that the rating of the alternator can be increased sufficiently to realize a full load rating of 600 amperes direct current per machine. Since it is physically impossible to increase the field flux with the present field excitation, these experiments embody the development of a means to provide the higher field voltage required.

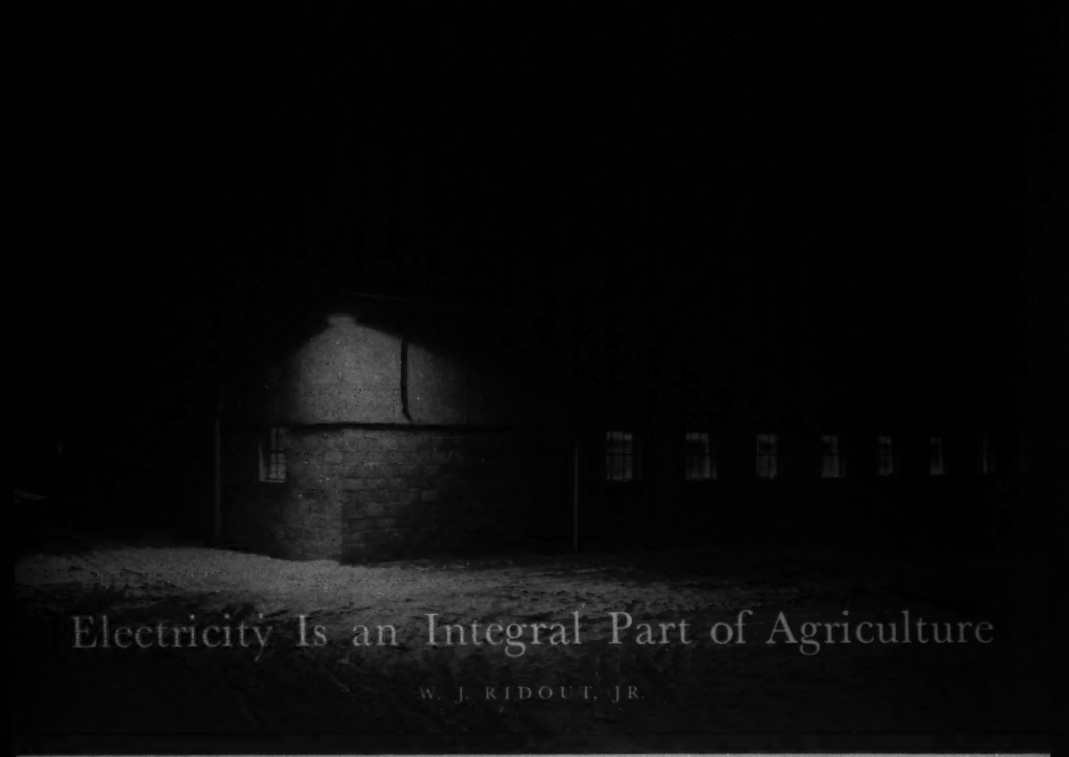
REFERENCES

1. Aircraft Electric Supply System, **J. E. Yarmack.** AIEE *TRANSACTIONS*, volume 62, 1943, October section, pages 655-8.

2. Carbon-Pile Voltage Regulators for Aircraft, **W. G. Neild.** AIEE *TRANSACTIONS*, volume 63, 1944, November section, pages 839-43.

3. Present D-C Aircraft Electric-Supply Systems, **H. C. Anderson, S. B. Crary, N. R. Schultz.** AIEE *TRANSACTIONS*, volume 63, 1944, June section, pages 265-72.

4. Characteristics and Application of Selenium Rectifiers, **E. A. Harty.** AIEE *TRANSACTIONS*, volume 62, 1943, October section, pages 624-9.



Electricity Is an Integral Part of Agriculture

W. J. RIDOUT, JR

It has been proved that electricity is an essential element in the progress of agriculture. Because of the great interest throughout the electrical industry in the application of electricity to farming, this article discusses the growth of farm electrification and indicates the problem involved in increased need for rural service.

IN THE EARLY 1920's the electrical utility industry in the United States was completing the greatest system of electric transmission line networks in the world. These lines were carrying electric power 24 hours a day from strategically located and efficient generating stations to practically every city and village in the United States. The foundation was laid for the beginning of farm electrification on a national scale. While some farms had electrical service prior to 1920, no large-scale farm electrification program could be carried out until the cities and villages had dependable 24-hour service. The farm electric lines naturally radiate from these cities and villages and such farm lines could not be energized efficiently and dependably until electric power in sufficient quantity was available in each of these urban centers. So, while few farms were served prior to 1920, the investment made by the power and light companies in utility property prior to that time was essential to successful farm electrification in the United States. It formed the foundation on which farm electrification could be built. It provided a supply of dependable low-cost electric power at a center in each farm area.

The utility industry began in earnest to start a national farm electrification program in 1922 and by 1930 had electrified 650,000 farms. The depression stopped all expansion for about five years at the end of which period the utilities again resumed the extension of electrical service to farmers.

In 1935 the Rural Electrification Administration was created and since that period it too has been active in extending service to farmers of the nation.

PRESENT STATUS

The latest available census figures on the number of occupied farms are for January 1945; new census figures will not be available until late 1951 and they will be for January 1, 1950. Assume then, that the number of occupied farms today is the same as it was January 1, 1945—5,600,000. The number of farms receiving electrical service from power and light companies as of December 31, 1947, was 2,082,316; the number of farms receiving electrical service from REA co-operatives was

Full text of a conference paper presented at the AIEE Southern District meeting, Birmingham, Ala., November 3-5, 1948.

W. J. Ridout, Jr., is rural service manager, Edison Electric Institute, New York, N. Y.

1,533,894; the number of farms receiving electrical service from all other agencies was 200,890. The total number of farms receiving electrical service on December 1, 1947, was 3,817,100. More than 550,000 additional farms received electrical service in 1948.

In the United States Census figures for January 1, 1945, it was shown that 856,000 farms were located either along existing lines or within one-fourth mile of such electric lines but, for one reason or another, were not taking service. Since that date undoubtedly a number of these farms have been connected to these lines but, on the other hand, many thousands of miles of lines have been extended into new territory and it is the best estimate of the Edison Electric Institute that at the present time there are about 725,000 farms that are not using electrical service but have been reached by electric lines.

From the figures just mentioned it appears that 4,550,000 farms in the United States have been reached with electric lines and that 3,817,100 of these actually are using electrical service. If from the total occupied farms in the United States the number already reached is deducted, it can be seen that there were about 1,050,000 farms in the United States that were located more than one-fourth mile from existing electric lines. As there were 550,000 additional farms served in 1948, it is apparent that the job of getting electrical service to the farmer will approach saturation by 1951.

In the year 1947 the electric power and light companies sold at retail more than six billion kilowatt-hours to the farms served by them. In addition they sold wholesale to the local co-operatives about two billion kilowatt-hours which in turn, were retailed by these co-operatives. The amount sold wholesale by the power and light companies to the local co-operatives was about 55 per cent of the co-operatives' total electrical requirements.

AGRICULTURAL SITUATION

On the whole, extension of electrical service to the rural areas of the United States has not been carried on with any considerable awareness of the agricultural revolution that is now in progress. Rather, farm electrification has been pushed almost entirely in disregard of the agricultural revolution. Look at the agricultural situation briefly. Relatively few realize the size of agriculture. It consists of 5,859,169 farms. In the aggregate, these constitute an investment in land, buildings, and equipment of more than 100 billion dollars. Farms have grown larger. The size of the average farm in 1920 was 148.2 acres while today the average size farm is 194.8 acres, an increase of 31.4 per cent.

The number of very large farms has increased. Farms of 500 acres and more grew from 217,000 to 264,000—an increase of 21.6 per cent.

As the farms grew larger, the worker unit declined. Workers per 1,000 acres dropped from 11.8 to 8.5—a decrease of 28 per cent.

Total annual farm income increased from 16 billions to 24 billions—an increase of 50 per cent.

The annual income per farm worker increased from $1,395 to $2,530—an increase of 64.2 per cent.

These changes occurred during a period when the population of the country was increasing from 106 million to 139 million. In that period farm population not only declined in proportion to the total, but it declined sharply in actual numbers from 32 million to 24 million—a decrease of 25 per cent.

Summing up the record of the quarter century, 1920 to 1945, it can be said that at the end of the period fewer workers were producing more goods to meet the needs of more people.

The cash income for the farmer was around 30 billion dollars for 1947. About half of that income went to 10 per cent of the farmers; about 80 per cent of it went to 30 per cent of the farmers. This division of cash farm income shows the differencc between farms and farmers, differences which are important now and which will become more important in farm electrification.

One of electricity's greatest advantages to the farmer and one which is of major importance at the present due to the need to keep farm income high, lies in its ability to make immediate savings in production costs, as soon as the farm is connected to the power lines.

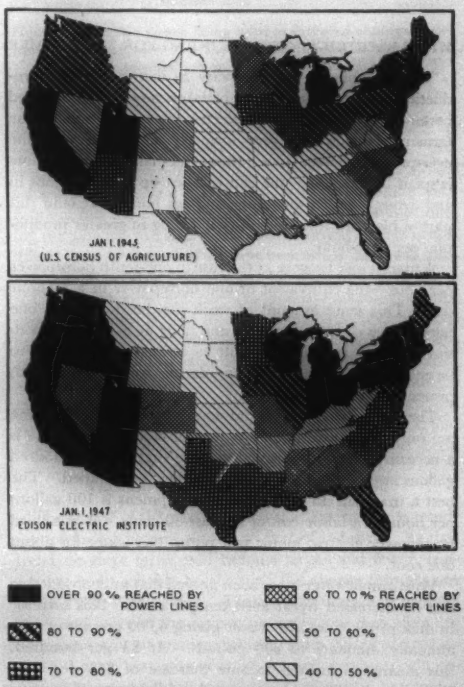


Figure 1. The availability of rural electricity

Percentage of occupied farms that have dwellings within one-quarter of a mile of an electric distribution line

Figure 2. Large centrifugal fans driven by motors in a typical hay drying installation

WHAT ELECTRICITY NOW IS DOING FOR THE FARMER

The part played by electricity in increasing farm production with less man-hours of labor nowhere is revealed better than in the use of electric motors to relieve the farmer of much drudgery formerly associated with the ever-present chores. Only about one-half a farmer's time is spent in the fields; the rest is taken up with odd jobs in and around service buildings and his home. It is in this part of his work that electricity is aiding in greater production per man-hour.

A man is said to work at the rate of one-tenth horsepower per hour—the equivalent of one horsepower in a 10-hour day. This same amount of work can be done by a one horsepower electric motor in one hour at a cost of two to three cents. It is not difficult to estimate the savings to be enjoyed where the motor can do the work of a man with present farm wages.

There are many uses for motors, of which the following are only a few examples. Water for stock and a home is a necessity on every farm. Suppose that several hundred gallons are required per day which must be pumped. The best a man can do with the best equipment is 100 gallons per hour at a labor cost of at least 30 cents. A one-third horsepower electric motor will pump this water for about one cent.

With ample water it has been proved that milk production can be increased by at least ten per cent. This increase in milk production with a cow giving 6,000 pounds of milk annually amounts to 600 pounds. At $3 per hundred, this means an annual income increase of $18 per cow. Thirty cows will produce enough additional milk to pay for the installation of an adequate water system for all purposes during the first year alone.

Tests have proved that egg production has been increased 19 per cent by running water at the correct temperatures. Suppose a farmer has 500 hens with 60 per cent laying, and a 10 per cent increase for winter months. This means 300 dozen more eggs which amounts to a big return on a very small investment plus the substantial saving in time and labor.

It is said that 25 per cent of hay is lost because of rain at harvest time. This loss can be eliminated almost entirely by a mow hay curing system. This method requires a system of ducts installed in the mow floor into which air is blown by a fan operated by an electric motor. The hay value is increased by $5 to $10 a ton at a cost of about $1 for electricity.

Research shows that a cow fed on mow-cured hay requires $27 less in grain and protein supplements per year. This saving applied to a 30-cow herd will pay for the mow curing installation in one season.

Hoisting hay into a mow is hard work but it can be done by an electric motor for about one cent per ton. The same motor that operates the hay drier can be used in most instances. Feed can be ground at 50 cents per ton; silos can be filled and emptied by electric power; barns can be cleaned; buildings and animals can be sprayed by insecticides; service buildings can be ventilated; and dozens of tools and farm machinery can be sharpened and repaired.

Electric milk coolers are great cost and labor savers. Extensive tests at the University of Kansas proved that milk could be cooled electrically at $9\frac{1}{2}$ cents per hundred pounds as compared to cooling by ice at $40\frac{1}{2}$ cents. The cost of the electric equipment was only $75 more than that for ice cooling.

Dairy water heaters pay for themselves in a short time. Hot water in a dairy is essential to sanitation and high-grade milk.

Figure 3. Modern dairy operation has been made possible by the utilization of electricity

Shown here are some very common uses: lighting, water heating, refrigeration, and water supplied electrically

Lighting in service buildings is a great convenience and prevents many accidents. In the poultry house lighting in the short winter days pays good dividends. Electric light bulbs, ultraviolet and bactericidal lamps increase egg production and keep birds healthy. Electric brooding of chickens long since has proved its value. A single pig brooder with a 150-watt lamp and reflector will cut loss by at least 50 per cent at farrowing time. The same saving also is made possible by lamb brooders.

WHAT ELECTRICITY WILL DO FOR AGRICULTURE IN THE FUTURE

The uses of electricity on the farm are many and varied. One listing describes more than 300 different ways in which electricity now is being used on farms, not including more than 100 household uses. It is impossible to foresee all the uses to which electricity will be applied. However, a new method of heating now is being studied, the heat pump.

The heat pump is ideally adaptable to farm use especially in heating and cooling broiler houses, hen houses, livestock barns, and farm homes. In The South and Southwest, poultry men believe the heat pump will be the answer to the hazard they encounter every summer in the effect of heat on laying hens. They also think that the heat pump can eliminate the use of hover-type brooders. Conditions on a farm, unlike those of urban dwellings, are more favorable for the installation of a heat pump in that there is plenty of ground space and usually a good water supply as sources of heat.

There is an old saying, "One swallow does not make a summer." So also, one successful experiment does not necessarily prove a scientific theory to be true or false. Both, however, may be considered to be indicators of that which is yet to be. The future well-being of agriculture and industry lies hidden in the field of electronics having to do with the radiation characteristics of the different elements, chemical components, living processes, and tissue.

The outgrowth of research and development in the field of electronics will revolutionize agricultural, industrial, and medical procedure, for in that portion of the field of physics having to do with these frequencies like "the pearl of great price," mentioned in Holy Writ, lies the keystone of all chemical action and life processes. It is predicted that if scientists will explore and develop this natural phenomenon earnestly and efficiently, agriculture will

1. Use only seed electronically tested for its germination, growing, and production vigor.

2. Select fertilizers and other plant foods because of the beneficial effect their radiated energies will have in the promotion of plant vigor, health, and productivity.

3. Treat the water supplied to plants and animals with the particular high-frequency wave required to promote health and production.

4. Utilize chemical and tissue radiations as major additions in the early diagnosis of plant and animal diseases.

5. Make use of these energies as an aid in the determination of proper remedies, be these remedies either natural food products, man-made chemical compounds, low-power short-wave radiation, or ultrahigh frequency.

Studies of phenomena accompanying the application of high-frequency currents to biological materials such as small animals, insect pests, bacteria, fungi, plants, and seeds, have uncovered methods of promised practical usefulness to agriculture. It is almost a breathtaking conception, but the irradiation of soils by high frequency during the plowing will lead to the possible eradication of grubs, mites, insect's eggs, and disease organisms, and will provide an enemy-free environment for the growing of crops.

Figure 4. Electric power being used to drive an ensilage cutter which chops the corn and blows it into the top of the silo—an essential job on most dairy farms

Ultraviolet rays are used to destroy micro-organisms, produce vitamin D, and to select or sort agricultural products. Infrared rays are used for dehydration of grains and forages, sexual stimulation of fowls (perhaps animals), and for therapy and general heating. High-frequency radiations are used to destroy disease and other objectionable organisms, to create artificial fevers, kill insects, and small animals, and to improve germination of seeds.

PROBLEM IN SERVING THE FARMER

The record of the past indicates that agriculture is trending towards a pattern similar to that of industry. As that trend develops farms will become larger and fewer, continuing and probably accelerating the change brought out in the 1920–1945 figures. These larger farms will perform more and more of the processing operations that often are performed now at greater distances from places of production. Lower cost shipment of finished products will replace higher cost shipment of raw products as processing, finishing, packaging, and marketing move closer to production. The electrical service requirements of such farms will be extremely high.

The revision of thought in farm electrification must be

towards service to large loads—factory loads—considerably distant from each other and with what might be called residential loads spaced between them. These rural residential loads will be larger than their urban counterparts. They will be in the homes of families depending principally for their livelihood and employment in the farm factories and in lesser degree, on the products of the soil. This article will not offer any new theory of rural distribution design to meet the service problem which has been indicated. It is likely that no one ever will come forward with any such theory of design. The problem itself will develop only slowly. The utilities must try to keep up with it as it develops and probably will discover once in a while, as they are discovering now, that they have fumbled and will have to do some more patching, but producing, finally, a tightly-knit, strong network of electrical distribution covering all the agricultural areas of the nation.

It has been proved definitely that electricity is an integral part of agriculture and therefore the electrical utilities are responsible in part for the progress of agriculture.

Measuring Radioactive Isotopes

Radioactive isotopes, now articles of commerce, are finding increasing uses in biological and medical experiments and even in clinical treatment of diseases. For these reasons the determination of the number of radioactive atoms in a sample of radioactive isotope has become a matter of greater importance. Uniform quantitative results in all laboratories can be obtained only by using procedures that will yield absolute measurements or by the use of uniform standards of comparison that will give, under proper conditions of measurement, the same result whenever the determination is made. Establishment of standards for radioisotope measurements, as for quantitative measurements in all fields of physical science, is the responsibility of the National Bureau of Standards. Detailed and accurate information therefore must be made available so that standard radioactive samples being furnished by the bureau to biological, medical, educational, and industrial laboratories can be used in a way to assure correct and reliable results. Two factors are involved in the preparation and use of these samples. First, methods and standards that are correct in principle must be used. Second, a reasonable degree of accuracy must be attained in all steps of the process not only of producing but also of using the standards.

Two gamma ray standard samples of Co^{60} sealed in 5-milliliter ampoules, one ten times the strength of the other, measured in rutherfords, one rutherford being the amount undergoing 10^6 disintegration per second

Essentially the measurement of a samlpe of a radioisotope is the measurement of the number of radioactive atoms present. This determines the strength of the source and involves three basic concepts: First, the total number of radioactive atoms present, N; second, the disintegration, or decay, constant, usually represented by λ, and obtained from the half-value period, T, by the relation

$$\lambda = \frac{\log_e 2}{T} = \frac{0.693}{T}$$

and, third, the disintegration rate, or "activity," λN, the number of atoms disintegrating in unit time.

Measurement of the rate of disintegration, that is, the number of atoms disintegrating in unit time, is necessary in order to determine the total number of atoms present. The disintegration rate is of course equal to the number of nuclear particles, usually beta particles or positrons, which are emitted per unit time from all atoms which disintegrate within this interval of time. This is true since, in general, one of these particles is emitted for each disintegration which takes place, but there are several important exceptions to this general rule.

The requirement that all disintegration particles must be counted per unit time is by no means simple. The principal difficulty is that these particles are emitted equally in all directions so that it is practically impossible to devise detecting equipment which will record all of them. The Geiger-Müller beta-ray end-window counter, for example, has a window through which the beta particles enter from a source placed in front of the window. The counter can record only that fraction of the particles which pass through it. This represents, from geometrical considerations alone, not more than 25 per cent of the particles actually emitted. At least three other factors may distort the results. They are absorption of particles in the window; absorption of particles in the source; and backward scattering of particles by the support of the source which directs through the window some particles originally emitted in other directions. The first two factors reduce the number from the correct value and the third increases it. Conceivably the contribution of all of these factors can be evaluated experimentally for a particular source and a definite arrangement of the apparatus. This not only requires considerable work but it must be repeated whenever changes are made in either the source or the apparatus.

Use of Sonar in Harbor Defense and Amphibious Landing Operations

ELIAS KLEIN THOMAS F. JONES

During World War II, harbors were guarded against sneak attacks by enemy submarines by a device known as Herald. To install, operate, and maintain equipment sufficiently simple for use at frontier bases required considerable development, including such engineering problems as submerged installations, remote controls, and operating adjustments. Ultrasonic devices also were developed, for use in establishing beachheads under darkness, each unit of which contained its own power device and method of self-destruction.

THE SONAR SYSTEMS described herein were developed to serve entirely different needs of the Armed Forces. One of them, the Herald equipment, guarded the entrances of our harbors against sneak attacks by enemy submarines. The other, the ultrasonic underwater beacon, guided landing parties in amphibious operations to a preselected beachhead. Both equipments are characterized by the emission of ultrasonic signals from a relatively fixed underwater transducer. In the Herald equipment the transducer is connected to the shore by a submarine cable. In the ultrasonic beacon the complete transmitting gear is enclosed in a buoyant, watertight can anchored by a cable to the bottom. In addition to the uses for which they were designed, both have been employed as homing beacons, as channel markers, and as warning devices for navigational hazards.

HERALD EQUIPMENTS

The Herald equipment, which derives its name from "Harbor Echo-Ranging And Listening Device," served its purpose of submarine detection either by listening to noise generated by the vessel's engines and propellers or by echo-ranging. With either type of detection, accurate information on the bearing of the intruder was obtained by a shore station through remote control of the sensitive beam of an underwater transducer. Echo-ranging determined, in addition, the range of the vessel by measuring the elapsed time between the transmission of an ultrasonic pulse along the beam and the reception of an echo from the target's hull.

All types of Herald equipments included two distinct installations, a shore station, and a sea station. The latter was located on sea bottom at the end of a submarine cable several miles long.

The shore station included an ultrasonic transmitting source, an ultrasonic receiver, a remote-control unit to direct the underwater ultrasonic beam, and an azimuth indicator. Because this station was readily accessible, its general design required no unusual engineering treatment.

Included in the sea station were a directional electroacoustic transducer, a means of training the ultrasonic beam, a means of transmitting azimuth data to the shore station, and a structure to support the active equipment erect and above the sea bottom. Repair or maintenance of this remote and relatively inaccessible unit was both hazardous and difficult. Also, special consideration was required to meet the needs of frontier bases. Therefore, the prime engineering requisite in the development of all models was to obtain simplicity, dependability, and ease of installations. For example, to eliminate slip ring, reduce inertia, and overcome bearing problems associated with rotating a massive electroacoustical transducer, the Heralds described in this article used a lightweight acoustic mirror tilted at an angle of 45 degrees to direct the ultrasonic beam. A horizontally mounted transducer sent acoustic energy vertically to the mirror which reflected the beam horizontally in a direction controlled by rotating the mirror about its vertical axis (Figure 1). Further examples will show the various stages in the development of three types of Heralds. They were the *QBC*, *QBD*, and *QBH*.

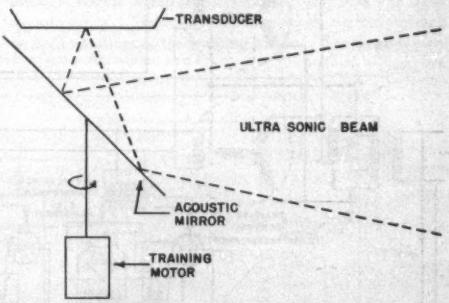


Figure 1. Ultrasonic beam directed by the acoustic mirror

Remote Control Development. A noteworthy electrical engineering problem common to all Heralds was that of the remote control system. This gave the shore operator a

Full text of a conference paper, "The Application of Sonar to Harbor Defense and Amphibious Landing Operations," presented at the AIEE Pacific general meeting, San Diego, Calif., August 26–29, 1947.

Elias Klein and Thomas F. Jones are both with the Naval Research Laboratory, Navy Department, Washington, D. C.

"Opinions or assertions contained in this paper are the private ones of the authors and are not to be construed as official or reflecting the views of the Navy Department or the Naval service at large." Naval Regulations, Article 113.

The authors are indebted to the Wallace and Tiernan Company, in particular to John R. MacKay and his staff, for supplying descriptive matter of certain components in the Herald gear and in the ultrasonic beacon. Also, to the Bell Telephone Laboratories for furnishing information on the sea cell.

means for rotating the ultrasonic beam at will and supplied him with continuous information as to the direction of the beam.

QBC. Remote control was accomplished in the first Herald by means of thyratron circuits to effect beam rotation and bearing indication. The training system consisted of a manual phase control, thyratrons, several miles of submarine cable, and a d-c motor which furnished motive power to rotate the beam as shown in Figure 2. The manual control was a phase transformer with a rotor winding whose voltage phase was dependent on its angular relation to three primaries which set up a rotating field. A request for change in azimuth was impressed upon the grids of four thyratrons in the form of a phase angle. This determined the polarity and magnitude of the voltage fed through the submarine cable to the d-c motor to control its direction and speed respectively.

Essentially the four thyratrons comprised two full-wave rectifier circuits connected to the same transformer so as to deliver a voltage, the polarity of which depended on which pair of tubes were conducting. The magnitudes of the phase-controlled grid voltages and a d-c grid bias were so adjusted that the simultaneous conduction of both pairs of thyratrons were prevented.

The azimuth of the sonar beam was reported to the operator by a dual-potentiometer repeating system in which one potentiometer was mechanically connected to the rotating mirror, and the other to the azimuth indicator in the shore station. The azimuth indicator, driven by a thyratron-controlled motor, stopped when the moving-arm voltage of its potentiometer was identical with that of the moving-arm voltage of the potentiometer attached to the sea-station mirror (Figure 3).

Although direct voltages were applied to the potentiometers, an a-c amplifier was used with the shore-station azimuth-indicator servomechanism in order to avoid the inherent zero-drift of d-c amplifying systems. The d-c unbalance voltage of the two potentiometer moving arms was converted into alternating current by a chopper consisting of an electromagnetic hummer and carbon microphone buttons. The resulting alternating voltage then was amplified and applied to a pair of small thyratrons which supplied the fields of a split-series-field motor causing it to move the indicator potentiometer toward balance. To prevent overshooting, a bucking voltage was added to the unbalanced voltage. This bucking voltage was derived from a tachometer and was therefore proportional to the speed of the indicator. Thus a negative torque was applied as balance was approached to provide the necessary damping action.

The control system just described was not entirely trouble-free. Considerable limitation was imposed on production of the urgently needed equipment and the complication of the circuits was a source of continual bewilderment to hastily trained maintenance personnel. Moreover, by employing a d-c motor in the sea station, it became necessary to use an air-filled compartment for the motor. The acoustic mirror in its liquid-filled compartment was rotated by a shaft which passed through a stuffing tube from the air-filled motor compartment. Even with the inclusion of a

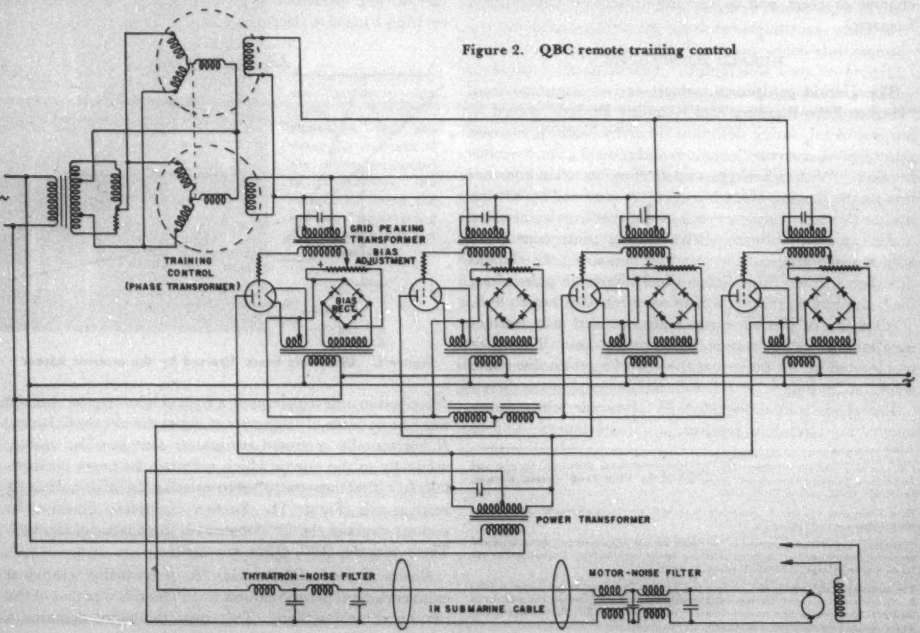


Figure 2. QBC remote training control

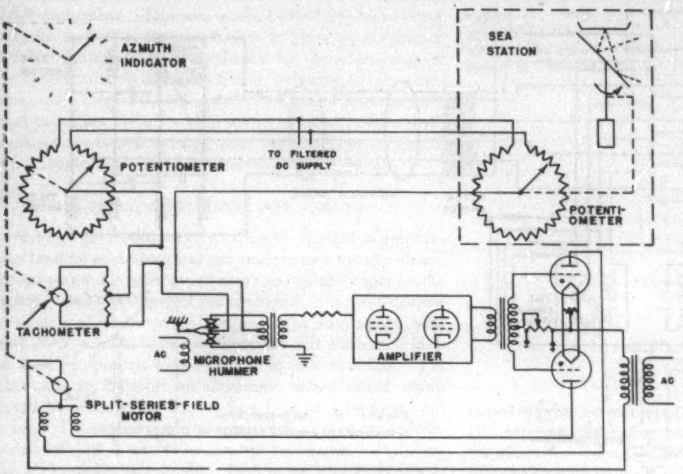


Figure 3. Dual-potentiometer repeating system schematic diagram showing use as part of azimuth indicator

nitrogen pressure system and a highwater alarm, the sea station required service periodically, either by sending a diver down, or by hoisting the unit to the surface. These shortcomings were still more noticeable at Navy outposts where adequate personnel and facilities were not readily available.

QBD. The *QBD* control system and corresponding sea station, developed in a few months, overcame the major objections to the earlier system. The sea unit was reduced to a one-compartment capsule and tripod which weighed less than half as much as the previous unit. No separate gas compartment with equalizing pressure was required, and the equipment needed no scheduled maintenance. The potentiometer system also was eliminated.

This relatively trouble-free capsule-type sea station was made possible by the adaptation to step-by-step operation of a commercial type of self-starting split-phase synchronous motor. The two field windings were center-tapped to obviate the necessity of switching the polarity of the supply voltage. Other minor modifications were made. The result was a variable-speed motor that could be operated remotely from a d-c supply and commutator located on shore.

Because there were no brushes or slip rings associated with this motor, it was possible to put the transducer, mirror, motor, and the various other electrical components of the sea station within a single oil-filled capsule with neither moving shafts packed through stuffing tubes nor other likely sources of failure.

The training control consisted of a manually rotated commutator which successively adjusted the biases of four vacuum tubes. These, in turn, drew anode current through the field windings of the training motor. The interconnec-

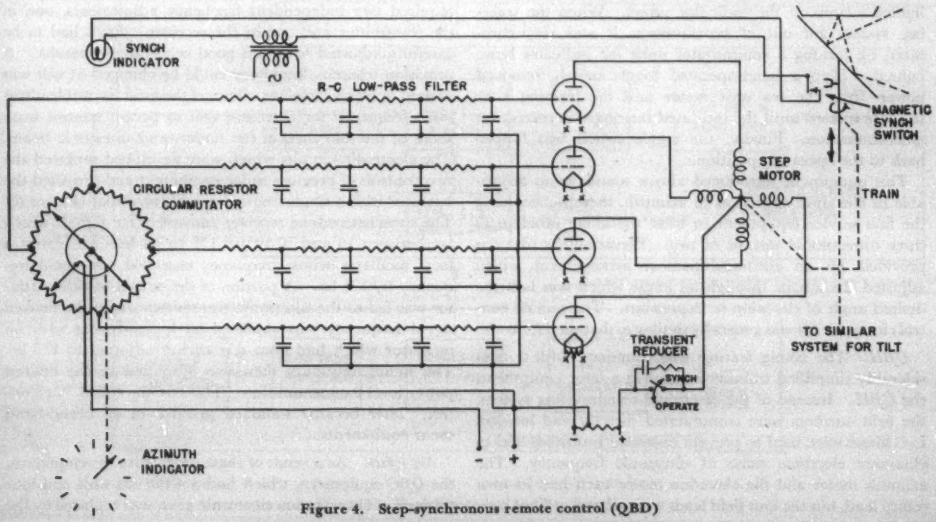


Figure 4. Step-synchronous remote control (QBD)

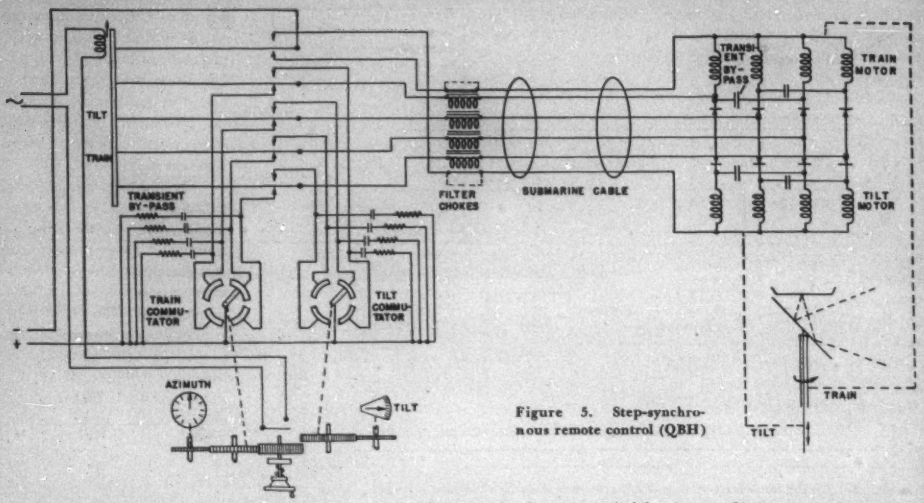


Figure 5. Step-synchronous remote control (QBH)

tion of commutator, tubes, and windings was such that a rotating field, generated in the motor, followed the control commutator synchronously. Excessive commutation transients and ultrasonic interference were prevented by resistance-capacitance low-pass filters connected between the commutator and the vacuum-tube grids (Figure 4).

The azimuth indicator was unusually simple. Because the motor followed the commutator synchronously, it was necessary only to provide a direct mechanical coupling from the commutator to the indicator. Synchronization was checked each revolution by means of a magnetic switch in the sea unit which closed at one specific bearing and lighted a lamp on the indicator panel. When the training system got out of synchronism, it was resynchronized by turning a commutator until the indicator lamp lighted. Then a hand-operated toggle switch removed power from the sea unit motor and the training control was rotated until the indicated bearing was correct for synchronization. Finally, the toggle switch was flipped back to the operating position.

This equipment introduced also a sound beam adjustable in elevation as well as in azimuth, thereby becoming the first service equipment to treat the sonar problem as three dimensional instead of two. Elevation, or tilt, was provided by an electromechanical arrangement which adjusted the mirror through an angle which was half the desired angle of elevation or depression. The remote control circuit for tilt was generally similar to that used for train.

QBH. The tilting feature was combined with a considerably simplified training control in a later equipment, the *QBH.* Instead of the electronic commutating system, the field currents were commutated directly and low-loss L-C filters were used to prevent excessive transients and to eliminate electrical noise of ultrasonic frequency. The azimuth motor and the elevation motor each had its own return lead, but the four field leads were shared. Thus only six leads were needed for the two 5-wire step motors. The effect of the fields of one motor shunting those of the other was prevented by the use of dry-disk rectifiers in series with each field winding. In this manner shunting current was blocked by the reverse resistance of one of the rectifiers; only that motor moved which had its return circuit completed. As shown in Figure 5, the control-wheel assembly, which turned either the train or tilt commutator according to its in-or-out position, operated leaf switches to transfer the motor field leads to the operating commutator.

Ultrasonic Unicontrol. Echo-ranging transmitters and receivers in existence at the time of the beginning of Herald required two independent frequency adjustments, one in the transmitter and one in the receiver. Each had to be carefully adjusted to obtain good echo-ranging results. A provision whereby frequency could be changed at will was desired in Herald to allow choice of the most favorable ultrasonic frequency for detection and to permit control from shore of the sharpness of the underwater ultrasonic beam. The electronic circuits which were developed replaced the two controls of previous sonar equipment and provided the operator with a single frequency-calibrated dial (Figure 6). The superheterodyne receiver converted the signal (which lay between 10 and 50 kc) to 175 kc by beating against a local oscillator whose frequency exceeded the signal frequency by 175 kc. A portion of the output of this oscillator was fed to the ultrasonic transmitter where the desired signal frequency was obtained by heterodyning with an oscillator which had been screwdriver-adjusted to 175 kc. The signal frequency then was amplified to the desired power level for transmission. This circuit, called "unicontrol," later became standard practice in all broad-band sonar equipments.

Net Effect. As a result of these progressive developments, the *QBC* equipment, which had a 4-ton sea unit and four cabinets of shore station electronic gear, was replaced by the

QBD equipment. This was more suitable for use at Navy outposts as well as for installation in continental harbors. Further simplification was effected by the production of the *QBH* gear. It had a sea station weighing less than two tons, and a single cabinet on shore. Figure 7 illustrates the final reduction in bulk with a saving of many tons of component parts as well as many man-hours of labor and made it possible to divert them to other urgent war needs.

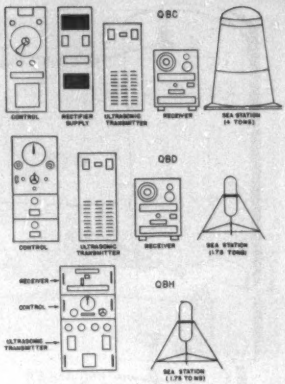


Figure 7. Progressive development of the three types of Herald gear

ULTRASONIC BEACONS *NAA* AND *NAB*

Among the developments which were applied to amphibious landing operations was the underwater sound beacon. It was planted in advance off shore to identify a spot on the beach. Being submerged and anchored, it did not disclose any intent of the proposed landing. The navy model *NAA* and *NAB* beacons were employed for this purpose. Both of these equipments were identical in their function. The plan was to transmit an ultrasonic coded signal which could be received by the leading boat of a landing craft wave. Transmission was programmed to start at a predetermined time within 48 hours after the beacon was planted by a reconnaissance group. Distinctive keying signals at specific ultrasonic frequencies were provided by means of cams. For example, it was possible to preset any beacon so that it would transmit one letter of the group ABNRV at a single frequency in the band 17–25 kc per second. The signalling continued for about 12 hours, after which time the apparatus automatically flooded and sank.

The sonar operator on the leading boat heard a prearranged coded signal through a model *QBG* receiving system. The latter consisted of a circular crystal transducer of nine inches in diameter and a compact receiver-amplifier. Originally, this system incorporated in the electronic unit a transmitter for sonar purposes as well as for echo-sounding and reef location. However, this dual function was abandoned in the present application because the "homing" job required the entire attention of the operator. The transducer or hydrophone was mounted on a shaft which projected below the boat and was rotatable. This enabled the listener to follow the maximum intensity of the beacon signal with a bearing accuracy sufficient to land within 50 feet of the beach marker.

Physically, the *NAA* beacon was cylindrical in shape, about 13 inches in diameter and 42 inches long. The over-all weight, excluding the anchor, was about 115 pounds with a positive buoyancy of 25 pounds. It was made up of two cylindrical sections clamped together by a series of wing nuts, Figure 8. The upper cylindrical section housed the electronic oscillator-amplifier with its associated components and the motor-program mechanism. To the lower section was attached a Rochelle salt transducer while inside this cylindrical space was a rack assembly with six lead-type

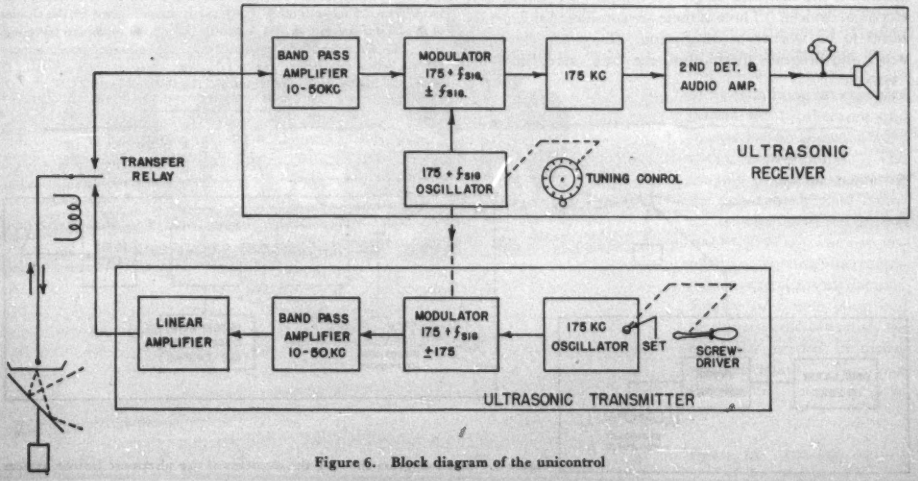


Figure 6. Block diagram of the unicontrol

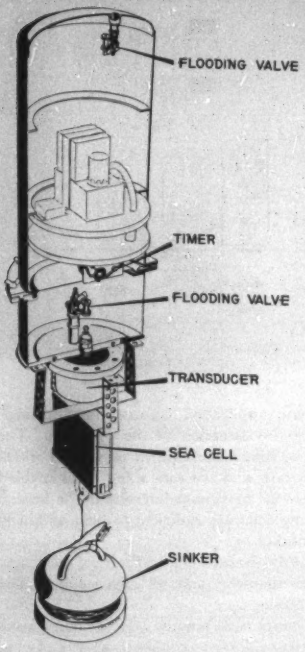


Figure 8. Cross section of the ultrasonic beacon

storage batteries. Both the upper and lower cylindrical sections contained sea valves, the design of which was to cause self-destruction of the buoy after it had served its purpose.

Besides the usual electronic transmitter and receiver which the beacon utilized (Figure 9), its operational requirements called for the inclusion of several unique mechanical and electrical devices. Three of these are considered sufficiently novel to be worthy of description. They are the time-delay and program mechanism, the "sea valve," and the "sea cell."

Timing Motor. With all the diversified clock mechanisms on the market and under development at the time the beacon was being designed, none fulfilled the specifications set down for amphibious landing operations. Among the more important requirements were: Positive make and break contact at any specified time up to 48 hours from launching; less than two pounds in weight; six independent contacts closing or opening at various intervals; the selected starting times to be accurate within one or two per cent of the time indicated on the program dial; power consumption for the entire timing mechanism to be less than 50 milliwatts.

This engineering feat was accomplished through the cooperative effort of the Navy and private manufacturers. The resulting motor assembly with time delay and program device consisted of a governor-controlled 6-volt d-c motor (speed, 1,800 rpm) which drove a gear mechanism and a series of cams.

Required timing intervals varied in length from a few minutes of operation to a 12-hour period after a possible delay of as long as 48 hours. Therefore, it was necessary to have a large reduction gear train with a tremendous ratio from the motor to the program cam gear shaft of 6,790,410 to 1. The speed of this shaft is one revolution in 62.893 hours. A reduction of this magnitude was made possible in a compact device ($5 \times 3 \times 2^1/_2$ inches) by utilizing a differential gear system with the two gears having a one tooth difference, that is, the difference between 45 and 46 tooth gears determined the movement of the rotating gear and the program cam shaft.

To point out the unique engineering features of this mechanism, the sequence of cam and contact operations are described:

(*a*). Before launching the buoy, it is desirable to check the operation of entire signalling system. The motor is running and the gear train is turning irrespective of open or closed cam. Turn cam lever (*K-104A*) counterclockwise (Figures 10, 11). This closes contact (*K-104*) and permits a test period of 15 to 30 minutes. During this time the selected code characteristics will be transmitted, 15 seconds on, 15 seconds off. The latter is accomplished by the closing of the heater contact (*K-103*) when the preoperational cam lever was set. The filament of the oscillator tube and vibrator power supply are on when the heater contact is closed. Code cam (*K-102.1A*) closes the high voltage and transmits the selected letter.

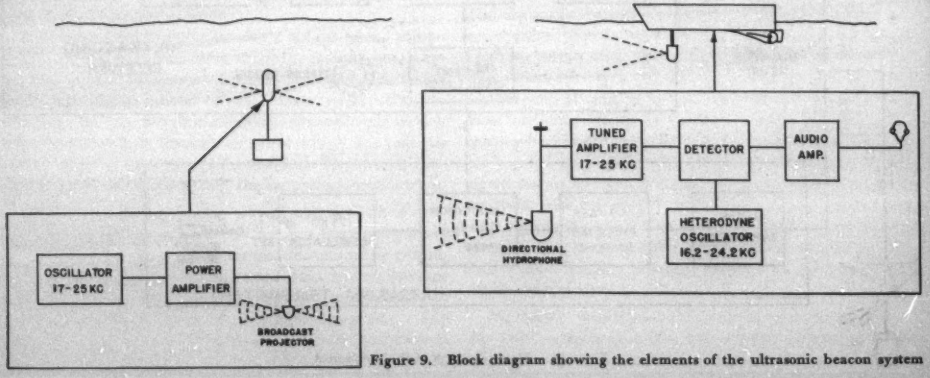


Figure 9. Block diagram showing the elements of the ultrasonic beacon system

(*b*). The preoperational test completed, the program dial cam (*B-101A*) is set to start transmitting, say, 23 hours later. Then the cycle will begin with the closing of the heater contact and the functional operation will repeat for about 12 hours.

(*c*). At the end of that period, the heater cam has moved so that the heater contact is opened. Then the sea valve contact closes and places the 6-volt supply across the glass electrolyte links (*E-101-1 and E-101-2*). In approximately 15 minutes the buoy is flooded and resting on the bottom of the ocean.

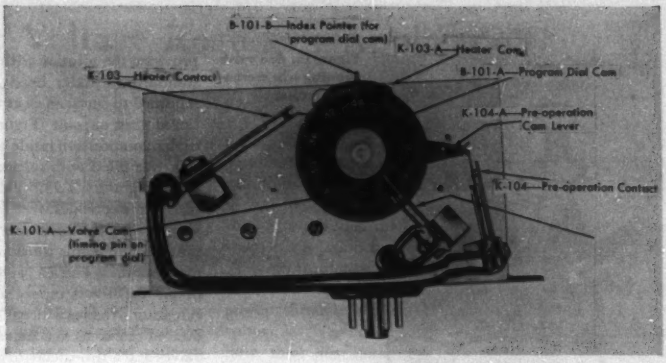


Figure 11. Side view of the program clock

Sea Cell. Another device associated with the beacon which was introduced "to make assurance doubly sure" was the sea cell. The lead acid battery with the "non-spillable" feature served well during the training periods. It was adequate as a power source and fulfilled all the requirements. But the remote possibility of getting acid into the electronic gear while launching the buoy, or not getting electrolyte into some of the battery containers when pressed for time during the preplanting period, brought the sea cell into the picture as an alternate power supply. The principal modification made was the connection across the motor supply of a grasshopper fuse which burned when the sea cell achieved sufficient terminal voltage to start the motor.

This development was one of the many notable achievements sponsored by OSRD. The particular cell which served as a power supply for the beacon was engineered and produced by commercial laboratories.

Sea Valves. It was a strategic requirement that the beacon be destroyed as soon after an attempted landing as possible. The usual method for achieving such a purpose was to insert a small explosive charge within the device. However, the necessary safety features involved in the handling and launching of an equipment containing an explosive proved too cumbersome and impractical for the small buoy under consideration. The simplest means for rendering the apparatus beyond recovery or functional recognition was to allow sea water to dissolve and corrode the components as well as to sink the unit. Soluble or fusible plugs and membranes did not satisfy the reliability needed in timing self-destruction. Nor was there enough energy left in the

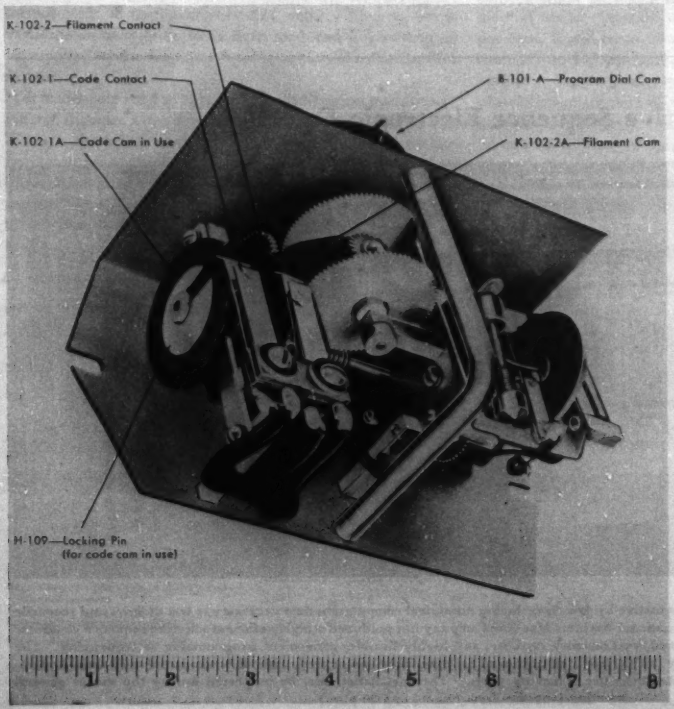


Figure 10. Cutaway drawing of the program clock

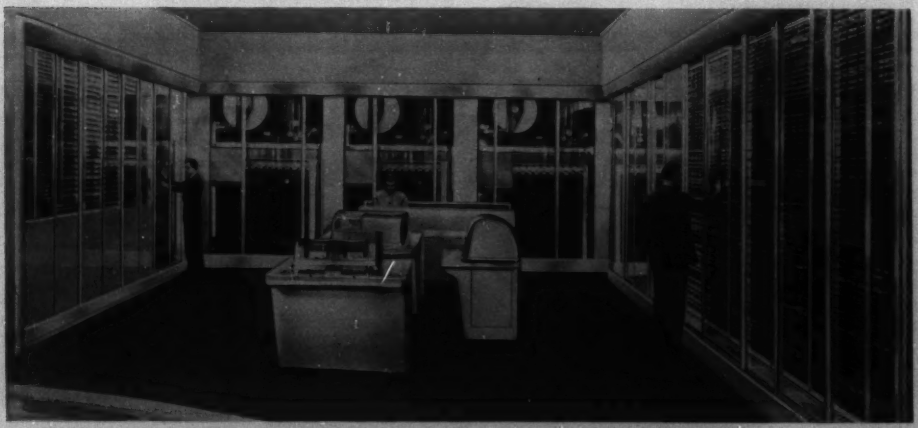
Figure 12. Sea valve showing trip mechanism

power supply to insure an opening by heating or burning.

Again, the engineering group of a private manufacturer provided the solution with a simple and reliable device. A standard sprinkler head as used for fire protection was modified to carry an electrolytic link in place of the conventional glass capsule (Figure 12) which is normally carried under compression inside the yoke. The actual electrolytic link was filled with sulphuric acid 31 per cent by volume, specific gravity 1.23. Electrodes of platinum and tipped tungsten electrodes were sealed in.

Following the functional period of 10 to 12 hours of operation, the ultrasonic transmitter is turned off by the program mechanism. The sea valve contact (*K-101*) is closed. This places the 6-volt supply across the glass electrolytic links. A resistor in series with each link limits the gas evolution to a desired rate so as to achieve both sequential operation of the valves and a time delay to guard against momentary contact closure during manufacture and while preparing the equipment for operation. By means of the resistors, the lower cylinder breaks first, which in turn opens the sea valve and permits water to enter the Rochelle salt projector. The upper link then bursts and causes the sea valve to open and flood the beacon. Thus, the oil in the projector is first forced out into the lower cylinder. When the water later enters the upper cylinder, it also is able to enter the Rochelle salt projector and dissolve the Rochelle salt crystals which are within.

Selective Sequence Electronic Calculator



To help make scientific effort more productive by greatly reducing numerical computation time necessary to test theories and reconcile them with experimental data, the International Business Machine Company has produced a highly efficient selective sequence electronic calculator. It combines electronic speed, vast memory capacity, and highly flexible, convenient programming or sequencing. The high speed of calculation is attained by the electronic circuits used for computing and control, with all fundamental arithmetical operations performed electronically and without the use of moving parts. The installation may be inspected during the winter general meeting (any day from 10 a.m. to 4:30 p.m.)

Feeder Voltage Regulator Application

J. N. GOSINSKI
ASSOCIATE AIEE

J. R. OBERHOLTZER
ASSOCIATE AIEE

PROPER VOLTAGE LIMITS have been established by the joint Edison Electric Institute–National Electrical Manufacturers Association committee on preferred voltage ratings for a-c systems and equipment. Many regulatory commissions have established voltage limits for power utilities operating within their jurisdiction. To stay within these established limits the design voltage drop from the primary at the first transformer ("feed point") to the customer entrance on the most distant service from the last transformer should be within 9 per cent or 11 volts on the 120-volt base. Experience and the results of studies in economic distribution system design have indicated definite apportionment of voltage drops beyond the feed point to various individual components, namely, primary, transformer, secondary, and service. It is considered that proper compensator setting on the voltage regulator to assure an optimum utilization voltage of approximately 118 volts will require a full load voltage level at the feed point or primary of the first transformer of 125 volts. The light load voltage level at the primary of the first transformer will be approximately 121 volts. Thus a 4-volt variation in voltage between light load and full load must be supplied by the regulator for this portion of a distribution system.

If feeders are used so that the first distribution transformer is some distance away from the substation, the voltage drop through the feeder obviously must be compensated by the regulator in addition to the drop beyond the feed point. Thus at full load the regulated feeder voltage at the substation must be higher than 125 volts by the amount of the feeder drop. The same will be true at light load. If a given distribution substation supplies both a short feeder and a long feeder, the minimum unregulated bus voltage will be determined by the full load requirements of the long feeder, and the maximum light load unregulated bus voltage by the light load requirements of the short feeder. When both short and long feeders are served from the same distribution substation, the unregulated bus variation must be smaller and therefore there is a reduction in the amount of compensation available for the power supply system.

The voltage regulation of the subtransmission system supplying the distribution substation will have a very distinct influence on the regulator range required. It is possible to design a power supply system such that voltage variations can be produced by its voltage regulating devices so that the distribution system feed point will have higher voltage at full load than at light load. In such a case, the voltage regulation requirements will be lessened and distribution regulators may not be required. However, in the more usual cases, the requirements for the transfer of bulk power through the transmission system are such that voltage levels are determined primarily by other considerations than distribution variations and distribution regulators are required. It has been found that radial-type subtransmission lines can be operated economically up to a full load voltage drop of 15 per cent. Table I indicates the regulator range which will be required for various combinations of power supply voltage regulation and distribution feeder drops.

The kilovolt-ampere capacity of the regulator usually is determined by the capability of the distribution circuit. Grouping of circuits for a single large regulator often is feasible when the load shapes are identical, such as commercial loads. Because the load factors may be 30 to 50 per cent, it will be satisfactory for the regulator to operate from 120 to 140 per cent of name-plate rating during peak periods. Single-phase regulators normally are used on substations to supply radial distribution circuits when phase unbalance must be considered. Three-phase regulators are preferable because of their lower cost per kilovolt-ampere on systems on which a phase balance can be maintained, such as commercial circuits and primary networks.

The actual voltage which the customer receives is determined entirely by the accuracy of control by the voltage regulator. Only recently has regulator accuracy been given the consideration which it deserves. While less accurate regulators are lower in price it has been found that one per cent regulator accuracy is entirely justifiable on the basis of the improved results.

Digest of paper 48-263, "Feeder Voltage Regulator Application on Power Systems," recommended by the AIEE transformer committee and approved by the AIEE technical program committee for presentation at the AIEE Midwest general meeting, Milwaukee, Wis., October 18–22, 1948. Scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

J. N. Gosinski and J. R. Oberholtzer both are associated with the Commonwealth and Southern Corporation, Jackson, Mich.

Table I. Regulator Range Requirements (120-Volt Base)

Distribution feeder drop—volts	0					4					8				
Regulation on supply side of distribution substation—volts	−4	0	4	8	12	−4	0	4	8	12	−4	0	4	8	12
Regulator voltage range required (a)	3(b)	7	11	15	19	6	10	14	18	22	9	13	17	21	25
Regulator range required (per cent)	0	±5	±5	±7½	±10	±5	±5	±7½	±7½	±10	±5	±7½	±7½	±10	±10

(a). These figures include 3.7 regulator volts required for the distribution system beyond the feed point and 3.3 regulator volts required for the distribution substation transformers.

(b). This range is borderline. If the distribution substation transformer drop is small, no regulators are required. However, high transformer drop or some allowance for additional distribution circuit drop would indicate the use of ±5 per cent regulators.

Frequency Modulation Design Trends

G. G. YOUNG

IN OCTOBER OF 1940, 15 construction permits for commercial frequency modulation stations were granted by the Federal Communications Commission (FCC). The beginning of commercial frequency modulation was received enthusiastically by the radio industry as well as the public. Advance advertising had created considerable public demand for the static-free and high fidelity performance promised by frequency modulation.

It is obvious that a high fidelity receiver whether it be for frequency modulation or amplitude modulation reception is necessarily more complicated and therefore more costly than a receiver of lower quality. The extended audio response and the low distortion required for good frequency modulation reception plus the need for high-voltage gain to operate the grid-bias limiter forced most prewar frequency modulation receivers into the higher price brackets. The "Armstrong system" receiver which incorporates the grid-bias limiter and the phase-shift discriminator was the only practical frequency modulation receiver circuit known prewar and was used in virtually all of the 400,000 receivers produced prior to the war.

In addition to the design problems resulting from the fidelity requirements of frequency modulation, engineers were faced with problems resulting from the high operating frequencies (42 to 50 megacycles). Some of these problems were microphonics, oscillator drift, and instability in both the radio-frequency and the intermediate-frequency amplifiers. In general it may be said that these problems were not new to design engineers but were made more acute because of higher operating frequencies and the high order of voltage gain required. Considerable progress was made in the standardization of components, the improvement of design techniques, and simplification of receivers. The cascade limiter was being replaced by the single stage limiter and as the number of transmitters in operation was increased, the sensitivity requirements became less severe.

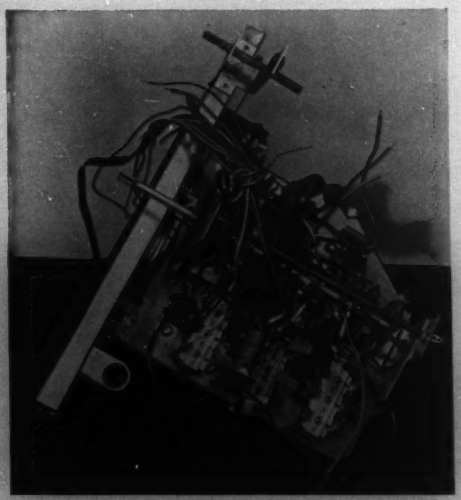


Figure 1. Bottom view, 5-band tuner using Guillotines for frequency modulation and short-wave tuning

During the war years, studies made by the FCC indicated that long distance interference resulting from sky-wave reflections would become a serious problem as the number of stations increased. In tests made near Washington, D.C., during 1945 the FCC obtained results indicating that interference would be negligible in the 100-megacycle region. Accordingly frequencies in the 88- to 108-megacycle band were assigned to all frequency modulation stations during January 1947.

The change to the 100-megacycle band resulted in numerous design problems. Amplifier in stability, oscillator drift, and microphonics were much more severe than on the 42- to 50-megacycle band. The tubes that had been used for broadcast receivers and prewar frequency modulation receivers are inefficient at 100 megacycles and the designers were forced to use the expensive *6AK5* and *6AG5* in most of the early prewar designs. The ganged capacitor, because of the common impedance to grid and plate circuits in the rotor shaft caused severe stability problems in the radio-frequency amplifier. As a result many novel tuning methods have been developed. The Guillotine tuner and the permeability tuned coil have been the most successful of these. The change from 4.5 to 10.7 megacyles as the intermediate frequencies makes stable gain and selectivity more difficult to obtain.

Many circuit improvements have been made and components, notably tubes, have been improved and reduced in cost. In addition there is a definite trend towards reduced performance, particularly in the audio systems of receivers. Table model receivers, many of them the transformerless type, have been manufactured in large quantities and many circuits have been developed both for cost reduction and for improved performance.

The further development of frequency modulation broadcasting depends on the public acceptance of frequency modulation receivers now in use, the ability of receiver design engineers to provide better receivers at lower cost, and upon the ability of frequency modulation broadcasters to furnish programs competitive with amplitude modulation programs.

Digest of paper 48-272, "Frequency Modulation Receiver Design Trends," recommended by the AIEE communications committee and approved by the AIEE technical program committee for presentation at the AIEE Midwest general meeting, Milwaukee, Wis., October 18-22, 1948. Scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

G. G. Young is with the General Electric Company, Syracuse, N. Y.

Planning a Large All-Hydroelectric System

M. WARD
MEMBER AIEE

H. A. SMITH
ASSOCIATE AIEE

This article presents a summary of the development of the all-hydroelectric Southern Ontario system of the Hydro-Electric Power Commission of Ontario, in Canada, and discusses the major factors to be considered in planning this type of electric power supply system.

THE DEVELOPMENT of any electric power supply system is governed largely by certain basic factors such as the extent of the area supplied, the total population, and the effect of terrain upon the distribution of that population and upon the nature and magnitude of industrial development in the area, all of which affect the total load demand. Fundamental differences exist between systems which supply demands by means of thermoelectric generation and those which make use of hydroelectric generation exclusively. In the latter case, the relative location of natural water power sites plays a prominent part in the development of the power system. Since system planning is concerned with devising the most economical method of supplying present and future load demands, consistent with the required degree of security and quality of service, the planning of an all-hydroelectric system is considerably different from the planning of a thermoelectric system.

THE SOUTHERN ONTARIO SYSTEM

This system supplies power throughout the southern portion of the province of Ontario, an area of approximately 47,000 square miles, having a population of approximately 3,500,000. The terrain varies in character from the sparsely-populated forest and lake region in the north to the relatively densely-populated arable territory adjacent to the Great Lakes basin with its highly industrialized urban centers and good farm areas.

In 1946, the total peak load demand on the system was 1,880,000 kw, created by 170,600 rural consumers, 297 municipalities having 673,680 consumers, and several large industrial customers engaged chiefly in electrochemical, metallurgical, and paper manufacturing. Figure 1 indicates the geographical outline of the area served and the bar graphs along its edges show the approximate disposition of the load along north-south and east-west axes in percentage of the total. These graphs illustrate that most of the demand is centered in the industrial areas of Toronto, Hamilton, and the Niagara peninsula, with decreasing load in a northerly direction.

The Southern Ontario system comprises three major divisions, the Niagara division operating at a frequency of 25 cycles, and the Georgian Bay and Eastern Ontario divisions operating at 60 cycles. Of these, the Niagara division has by far the greatest load demand, accounting for approximately 85 per cent of the total. At the present time, integration of the three divisions is accomplished by five frequency-changers, having 106,000 kva combined capacity, and one 110-kv 60-cycle tie line, which allow some degree of flexibility in peak and energy transfer between the divisions.

In 1946, approximately 42 per cent of the total generating capacity supplying the system was situated on the Niagara River, 50 per cent in "eastern generation" on the Ottawa River and in the province of Quebec, and the remaining 8 per cent was distributed throughout the Eastern Ontario and Georgian Bay divisions. Approximately 88 per cent of the total eastern generation was transmitted an average distance of 240 miles to terminal stations within the Niagara division, the remainder being absorbed by the adjacent Eastern Ontario division.

The long-distance transmission of power from the east is accomplished by the use of 1,173 circuit miles of 220-kv transmission line supplying two 220/110-kv transformer stations having a combined capacity of 640,000 kva. From these terminal stations and the remaining generating sources, transmission to the major distribution centers is accomplished by means of 2,294 miles of 110-kv lines. The subtransmission systems supplying municipalities employ 26-kv and 13.2-kv lines in the more densely loaded areas of the Niagara division, and 44-kv lines in the less densely loaded Eastern Ontario and Georgian Bay divisions.

The boundaries of the divisions, and the location of the major generating sources, 220-kv and 110-kv transmission lines, 220-kv terminal stations, 110-kv major distribution centers, and frequency-changers are indicated in Figure 1.

EARLY DEVELOPMENT

At the beginning of the century, development of electric power was in progress in all three divisions. Because of the abundance of water power available from the Niagara River and its proximity to large centers of population, the greatest development took place in the area of the Niagara peninsula. Relatively small, isolated hydroelectric plants, as well as a few small thermoelectric units, were in use in the other two divisions for supply of adjacent municipalities. Transmission systems were simple in design, consisting in general of a few radial lines.

In 1906, The Hydro-Electric Power Commission of Ontario was formed, its function being to generate, transmit, and deliver power upon request to any city, town, village, or municipality in the province. Initial operations of the commission commenced in 1910, with the purchase

Essential substance of paper 48-265, "Planning the Development of a Large All-Hydro System," recommended by the AIEE system engineering committee and approved by the AIEE technical program committee for presentation at the AIEE Midwest general meeting, Milwaukee, Wis., October 18–22, 1948. Not scheduled for publication in AIEE *TRANSACTIONS*.

M. Ward and H. A. Smith are both with the Hydro-Electric Power Commission of Ontario, Toronto, Ontario, Canada.

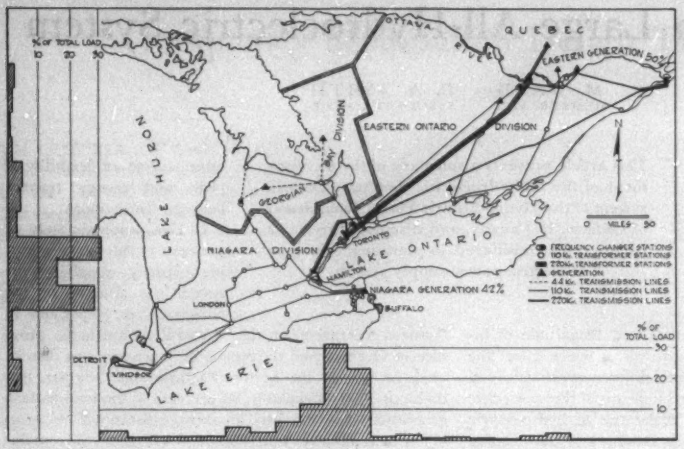


Figure. 1 Diagram of Southern Ontario system showing area served, main system facilities, and approximate distribution of loads and resources

of power from the Ontario Power Company at Niagara Falls and the delivery of this power to seven municipalities.

Until 1922, the system requirements were relatively simple and extensions to the transmission system were radial in character. The load demands in the 60-cycle divisions were met by the purchase and construction of small hydraulic sources at convenient points and extension of the transmission system in radial form at voltages of 22 kv, 33 kv, and 44 kv. Because of an anticipated rapid increase in load demand, which greatly was accelerated by World War I, Niagara division transmission was extended at 110 kv, the highest voltage attained in practice at that time. The selection of this transmission voltage had considerable effect on the subsequent development of the division, since its use permitted the transmission of Niagara power to the extremities of the division, and later allowed the direct superposition of a 220-kv system. By 1916, it was evident that additional resources soon would be necessary in the Niagara division, and plans were laid for construction of a 10-unit plant at Queenston, on the Niagara River, which would double the system resources.

COMMENCEMENT OF PLANNING

After completion of the Queenston development, studies of load growth indicated the need for additional resources by 1928. Since Niagara resources had been developed to the limit set by international agreement, it was evident that the only hydraulic sites were remote from the centers of utilization and, for the first time, system planning in its modern concept was applied. The basic problem was to establish a long-term plan for the supply of future load growth, including in the analysis a comparison of the alternative sources of supply. These studies included the economic and other phases involved in steam-electric generation and, alternatively, the corresponding phases involved in the development of available hydraulic sites, distant from load centers, and requiring long-distance high-capacity transmission. As a result of these studies, it was decided to supply future load growth from eastern hydraulic sources located on the Ottawa River and in the neighboring province of Quebec.

THE FUNDAMENTAL PLAN

The long-term plan evolved was to overlay the existing 110-kv network with a 220-kv network. By locating step-down stations at strategic points within the 110-kv system, it would be possible to augment the supply to each natural geographical component with infeed at 220 kv at the load center of each area. In this way, further construction of 110-kv lines could be held to a minimum with increasing amounts of power, transmitted from eastern sources, injected into the system in accordance with the load demand.

The effectiveness of this plan is illustrated by the fact that the increase in circuit miles of 110-kv line in the Niagara division from 1929 to 1947 has been less than 2 per cent compared to a corresponding load growth of over 130 per cent. During World War II, when strategic materials were at a premium, the construction of a new 220-kv terminal station, required to supply increased loads, actually permitted the removal of certain 110-kv lines for use in the northern part of the province. With the broad concept of the plan developed prior to 1928, the actual implementing of the plan was varied to suit conditions as they occurred, and has been described in papers by the late E. T. J. Brandon[1] and by A. H. Frampton and E. M. Wood.[2]

DEVELOPMENT OF THE PLAN TO DATE

Figure 2 shows in schematic form the Southern Ontario system as it existed in 1927. The three divisions were separate entities; sources of generation in the 60-cycle divisions were at various locations within their boundaries, and in the Niagara division were on the Niagara River with radial 110-kv lines to the four major geographical subdivisions—West, Central, Hamilton, and Toronto.

Figure 3 shows the system as it existed in 1930 with the initial phase of the plan for transmission of eastern power in operation and a frequency-changer interconnection between the Niagara and Georgian Bay divisions. The 220-kv terminal was located within the metropolitan area of Toronto, transforming both to 110 kv for connection to the main system, and to 13.2 kv for direct distribution of power to the local load. By this means, construction of an additional 110-kv station for the Toronto area was deferred until 1942.

Figure 4 shows the system as it existed in 1941. The second 220-kv terminal was located at Burlington, some 30 miles west of Toronto. The site chosen was at a point where several 110-kv lines intersected, thereby eliminating the construction of additional lines. Also, it was only three miles distant from the important manufacturing city of Hamilton and adjacent to the Central subdivision. By splitting the 110-kv bus at the station, it was possible to operate at two voltage levels, thereby providing increased power supply to the Central subdivision and to Hamilton and Toronto.

Figure 5 shows the system as it will exist next year with the establishment of a third 220-kv terminal on the westerly outskirts of the metropolitan area of Toronto. The location of this terminal is also in accordance with the original principle—that the construction of additional 110-kv lines should be held to a minimum. It should be noted that, in this stage, the 25- and 60-cycle divisions are integrated by means of frequency-changers at three locations, and the 60-cycle divisions by means of a 110-kv tie line.

Figure 6 shows future extension of the system for the incorporation of two new developments on the upper Ottawa River. It is planned to have these facilities operating by the end of 1952, thereby completing the plan originally developed.

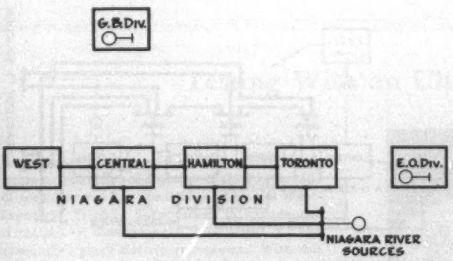


Figure 2. Schematic form of Southern Ontario system, 1927

FACTORS AFFECTING DESIGN OF THE ALL-HYDRO-ELECTRIC SYSTEM[3]

General. The ultimate goal of any electrical utility is to supply customer demand at minimum cost. Systems employing hydraulic generation are confronted with the fact that sites are fixed by nature and, in general, the cost of the supply system progressively increases since the sources closest to utilization centers are developed first. On the other hand, systems employing thermal generation are free to select the location of generating stations, and, in order to supply system demand, are required only to install sufficient peak capacity as they are not dependent upon the vagaries of nature. Furthermore, systems employing hydraulic generation require not only the planning of adequate peak capacity, but also careful consideration of the seasonal variation in the quantity of water available.

Determination of Generating Capacity Requirements. The determination of the need for new generating capacity naturally depends upon a forecast of future load. Within the commission, the making of load forecasts has been the duty of a committee, the members of which are engineers drawn from the various departments connected with the planning, operational, and consumer service functions of the organization. In general, the historical method is used and the load demands of the past are projected into the future. The yearly peak, which invariably occurs in December, determines the amount of peak capacity required and, therefore, long-term estimates deal basically with this quantity. It is also necessary to provide the requisite energy capacity which involves a comparison of load requirements with generation for each month of the year. To do this, duration curves of available river flow at each plant for each month of the year are used. These curves take into account the extent to which the natural flow of the river may be controlled by the construction of storage facilities, and the dependable energy capacity of the plant is based on the flow which is available for 85 per cent of the time. In Ontario, minimum river flow usually occurs in February and hence it is quite possible for the energy demand in this month to dictate the extent to which new developments must be made.

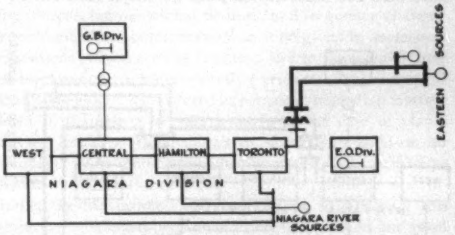


Figure 3. Schematic form of Southern Ontario system, 1930

Provision of Reserve Capacity. Provision against contingencies which result in loss of dependable peak and energy capacity on the all-hydroelectric system are somewhat different from those of the steam-electric system. In the latter, loss of a generator unit not only reduces peak capacity, but also reduces the system's potential energy capacity whereas, in the former, loss of a unit does not necessarily reduce energy capacity unless the plant is designed for 100 per cent load factor operation and has an invariable water supply. Usually, hydraulic plants do not have an invariable water supply and hence do not operate at 100 per cent load factor, except possibly during

the Spring runoff. To provide against loss of peak capacity, the commission has adopted the policy of installing spare units in selected plants and of supplying power to certain large electrochemical and electrometallurgical customers under contracts which make provision for the interruption of all or part of those particular power supplies for stated intervals during the load season when peak reserve is most desirable.

Selection of Site for the New Plant. At the present time sites having potentialities commensurate with the needs of the Southern Ontario system are on the Ottawa River, more than 200 miles distant from the major load centers.

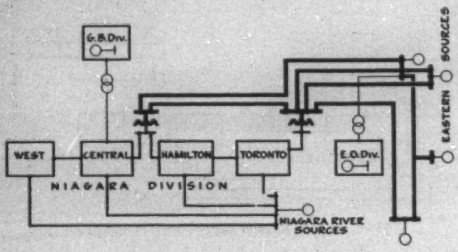


Figure 4. Schematic form of Southern Ontario system, 1941

Therefore, the transmission facilities required for the delivery of the power to centers of utilization form a considerable part of the over-all cost of the system extension. When there are several sites available, before a choice is made it is necessary to fit each of the alternative developments into the system, matching peak and energy potential against the forecast of demand. It is also necessary to determine the transmission lines and other facilities required to integrate the new plant with the system.

At this stage, extensive use is made of the network calculator, by means of which the transmission systems dictated by the various alternative sites are studied and developed. The flow of real and reactive power throughout the system, voltage regulation, synchronous condenser requirements, and system losses are determined under steady-state conditions. The network calculator also is used to determine the stability of the system under fault conditions and, by this means, the effect of variation in generator transient reactance and moment of inertia is assessed. The value of mid-point switching stations and matters pertaining to circuit breaker operation, such as maximum permissible clearance times, automatic reclosure, and single-pole switching, also are determined.

In fitting in the new plant, a full appreciation of the existing system is necessary and consideration must be given to whether any specific type of operation is to be established for it. Its geographical location will affect the decision, since, if operating on the same river with other plants, its operating load factor may be fixed in advance unless sufficient storage can be developed between plants. The available head on the plant influences the size and type of unit to be used, and the size of the units influence the design of the plant in so far as the number of units connected to one step-up transformer is concerned.

With all these factors given consideration, a comparison of the respective sites from an economic standpoint is made. Quite often the cumulative cost including fixed and operating charges indicates that it would be advisable to incur a relatively high initial investment. From these various studies, the most advantageous site is selected and specifications for the development and the necessary transmission, terminal, and switching facilities are prepared.

Utilization of Power. Apart from supply of rural consumers, The Hydro-Electric Power Commission of Ontario acts largely as a wholesaler supplying power in bulk to a municipality which then retails the power over a distribution system owned and operated by the municipality. In planning the step-down transformer stations for supply of the various municipalities, every effort is made to locate the station as close as possible to the load center of the area which it serves, and to deliver power to this station at the highest practicable voltage.

In general, cities and large towns are supplied from 110-kv transformer stations, while the smaller municipalities outside the main urban centers are supplied from 26.4- or 13.2-kv distributing stations by means of feeders originating at the high-voltage stations. When the need for additional transformer capacity in the 110-kv station supplying the area is indicated, the course of action to be taken is dictated by whether the area outside the urban center or the urban center itself is causing the increased demands. If the former is the cause, studies are initiated to determine whether a new station should be constructed or the existing one enlarged. In this case, it is usually sufficient to assume that each distributing station represents a concentrated load and to consider the effect of locating a new station as close as possible to the center of gravity of these loads. In recent years, the commission has found it economical to construct new 110-kv stations at these points, utilizing 8,000-kva 3-phase units, and semiattended in character. If the urban center is the cause, the loading of the distribution system owned by the municipality is considered first. Even though the municipality owns its distribution system, the commission still is concerned with the over-all economy and, should the system be heavily loaded, studies are made to determine the economies to be effected by installing a new 110-kv station. In this case, because of the much greater load density, the problem is studied on

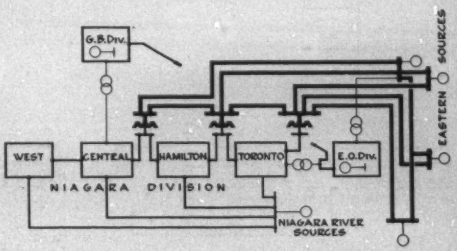


Figure 5. Schematic form of Southern Ontario system, 1949

the basis of load contained within each one-half mile square.

In planning a new step-down station, the predominant factor governing its location is the determination of the

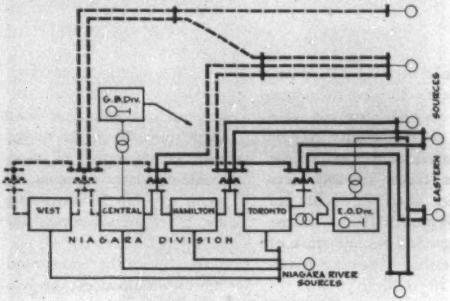


Figure 6. Schematic form of Southern Ontario system, 1952, showing planned extensions

load center of the area which it is to serve, tempered by other factors such as accessibility by rail, convenience of connection to existing high- and low-voltage transmission facilities, terrain suitability, and staff accommodation.

Automatic Load and Frequency Control and Telemetering. In order to maintain constant frequency operation of any system and, at the same time, maintain scheduled flows of power over interdivisional ties, careful control of generation in each division is required. Allowance must be made for variations in the load demands, and generating units in each division must be operated as regulating devices. If only one plant is used to regulate a relatively large load division, the efficiency of that plant may be reduced considerably due to units operating over a range of loads. Optimum results may be obtained by using a sufficient number of regulating units in plants having low load factor operation and turbines with "flat" efficiency curves.

In planning system extensions such as additional generating sources, interdivisional tie lines, and frequency-changer interconnections, consideration must be given to associated extensions of load control facilities, and to the telemetering of information to main operating centers. In the case of hydraulic plants, telemetered information regarding forebay level is of importance, particularly in the case of plants having intake through canals or those with little or no pondage. On the commission's Southern Ontario system, telemetering and automatic control equipment are installed in the power supervisor's office in Toronto, this point being selected because of its central location and good communication facilities to all parts of the system.

REFERENCES

1. The 220,000-Volt System of The Hydro-Electric Power Commission of Ontario, **E. T. J. Brandon.** AIEE *TRANSACTIONS*, volume 49, 1930, pages 1400–17.

2. The 220,000-Volt System of The Hydro-Electric Power Commission of Ontario—II. **A. H. Frampton, E. M. Wood.** AIEE *TRANSACTIONS*, volume 60, 1941, pages 1215–21.

3. Factors in the Economic Supply of Energy in Hydroelectric Systems, **A. H. Frampton, G. D. Floyd.** AIEE *TRANSACTIONS*, volume 66, 1947, pages 1117–24.

4. Hydroelectric Power Plants, **A. H. Frampton.** *ELECTRICAL ENGINEERING* April 1946, pages 151–9.

Testing With an Ultrasonic "Stethoscope"

An ultrasonic "stethoscope" that enables engineers to examine solid pieces of steel by means of sound waves has been devised by the Westinghouse Electric Corporation to assure the detection of flaws in the production of the company's giant electric generators. With this new technique, ultrahigh-frequency sound waves are transmitted through massive steel parts. By using a crystal similar to that used in a phonograph pickup arm, electric impulses are changed to sound waves, which, when projected through the metal, reveal tiny cracks, cavities, or foreign particles, and reflect sound back to the crystal. Changed back into electric impulses, these reflections appear as bright vertical lines on the viewing screen of the electronic receiver. By measuring the time it takes the sound waves to go through the metal and bounce back to the crystal, metallurgists can find the exact location of any flaw. This reflected sound method is as accurate as an X ray, and is able to penetrate thicknesses that X rays cannot reach.

Electronic Protective Relays

R. H. MACPHERSON
ASSOCIATE AIEE

A. R. VAN C. WARRINGTON
MEMBER AIEE

A. J. McCONNELL
ASSOCIATE AIEE

Although electromagnetic protective relays are adequate for present requirements, the ever-increasing demand for higher speeds and greater accuracy and dependability seems likely to exceed the capabilities of relays now available. However, the trend toward electronic control circuits in other branches of electrical engineering, coupled with the recent improvements in the design and manufacture of electronic circuit components, indicates a possibility of overcoming these limitations.

IN THEIR PRESENT state of development, electromagnetic protective relays possess characteristics and reliability well abreast of the demands of power-system protection. However, the attainment of this status has been fraught with many problems for which ideal solutions have not been found. Further development in system design, such as high-speed reclosing, together with the increasing demand for higher degrees of accuracy, speed, and dependability, have accentuated these problems to a point where the inherent limitations of electromagnetic relays are raising barriers to the achievement of desired goals.

The increasing use of electronic circuits in nearly all branches of electrical engineering, coupled with the great strides that have been made recently in the design and manufacture of electronic-circuit components, seems to point the way to the use of electronic means for lifting these barriers.

In view of the widespread interest in electronic devices of all kinds, it is not surprising that protection engineers have developed a keen interest in electronic protective relays. This interest, however, has not resulted in general enthusiasm for such relays because many relay engineers are satisfied with electromagnetic relays. On the other hand, some operators would welcome a complete line of electronic relays. Some of the latter group have been inclined to attribute the lack of electronic relays to, what is to them, a reactionary attitude. This article is intended to present both a report of progress, and an explanation of the present limited availability of such relays.

The limited number of electronic relays should not be assumed to indicate any serious lack of interest or ingenuity. To the relay engineer, electronic circuits are merely one of the many tools available for obtaining the characteristics necessary for discrimination between normal and abnormal conditions in a power system. Typical of such tools that have been available to relay engineers for many years are nonlinear resistors, rectifiers, and neon lamps.

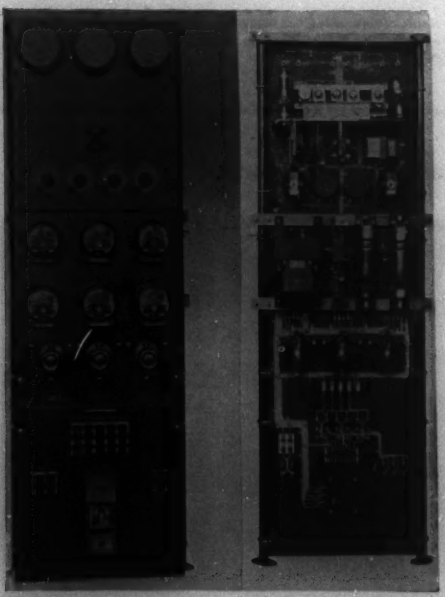


Figure 1. Early electronic pilot relay for carrier-current applications

EARLY WORK

The following examples show that electronic relays are by no means new, and that manufacturers have been aware of their potentialities ever since practical tubes were available.

In 1927, A. S. Fitzgerald developed an electronic pilot relay system[1] (Figure 1) to overcome the limitations of pilot wires when operating over considerable distances. This scheme was abandoned because of the short life and the high cost of tubes available at that time, but a somewhat similar scheme is now in active use as the phase-comparison

Full text of paper 48-310, "Electronic Protective Relays," recommended by the AIEE relay committee and approved by the AIEE technical program committee for presentation at the AIEE Midwest general meeting, Milwaukee, Wis., October 18–22, 1948. Scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

R. H. Macpherson and A. R. van C. Warrington are in the relay engineering section, switchgear divisions, General Electric Company, Philadelphia, Pa.; A. J. McConnell is in the central station engineering divisions, General Electric Company, Schenectady, N. Y.

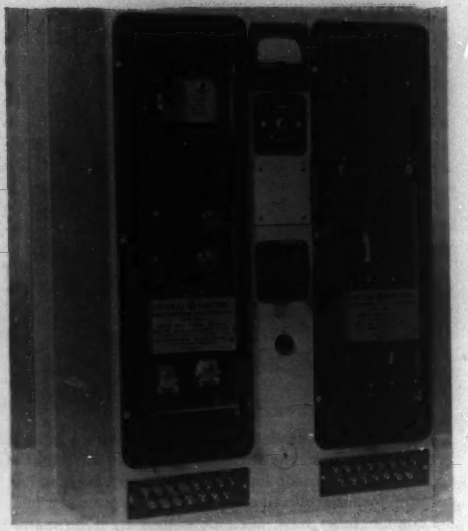


Figure 2. Phase comparison pilot relay

relay[2] (Figure 2). Fitzgerald's was the first well-known application of electronic protective relays.

In 1931, Rolf Wideroe of Norway developed electronic circuits for most of the common types of protective relays and described them in a paper presented before the Institute in 1934.[3]

In 1932, in the United States, a laboratory sample electronic-reactance relay[4] was built and tested, but at that time the electromagnetic reactance relay was fully adequate for the needs of the industry and no steps were taken to put the electronic relay into production. This type of electronic relay was built because it embodied all the common relay principles in a single relay and hence presented all the problems of the different types, such as overcurrent, undervoltage, directional, phase angle, and differential relays. In other words, the reactance relay was a good guinea pig. The experience gained from this development was destined to become valuable for future developments.

Directional-comparison carrier-pilot relaying, using electromagnetic directional relays to discriminate (by their joint action) between internal and external faults[5,6] (Figure 3), came out in 1930. This type was extended in 1936[7,8] to include the back-up function in the form of distance relays (Figure 4). Neither of these can be classed as an electronic relay, because the discriminating relays are electromagnetic and the electronic circuit is limited to transmitting and receiving signals along the transmission line; that is, only the communicating channel is electronic. On the other hand, this application has been so successful and widespread that it is valuable as a source of information on the life and behavior of electronic components such as tubes, tube sockets, and small resistors.

An electronic synchronizing relay (Figure 5) was built in 1934 and has been used widely ever since. This was a case where the use of an electronic device was justified because it could achieve results not economically obtainable with an electromagnetic relay.

In 1936, an electronic timing meter (Figure 6) was designed for testing high speed relays. It measured down to one millisecond, and hence was very much better than existing synchronous timers, and was considerably more convenient to use than an oscillograph.

Since then there have been a number of miscellaneous electronic applications to relays, mostly in connection with the war effort; but, in general during the last ten years, there have been few cases where it was believed that an electronic relay would do the job better than an electromagnetic relay.

CARRIER RELAYING

Carrier relaying is the principal source of experience with tubes. In the early days of carrier relaying, tubes had a very irregular life and required frequent replacement. This led to the general specification that the tripping of a circuit breaker should not depend upon the proper operation of a tube.

Tubes have improved gradually, so that today the average replacement does not exceed once a year. Improvement in tubes has reduced skepticism to the point where tripping via tubes is considered acceptable. This is shown by the fact that available forms of phase- or current-comparison relaying require tube operation for the tripping function.

Why has carrier-current relaying attained such widespread use, whereas other types of electronic relays are few? The major reason is undoubtedly that carrier relaying has accomplished a highly desirable result not economically feasible by any other known method. This

Figure 3 (left). Directional comparison carrier pilot relay

Figure 4 (right). Distance carrier pilot relaying equipment

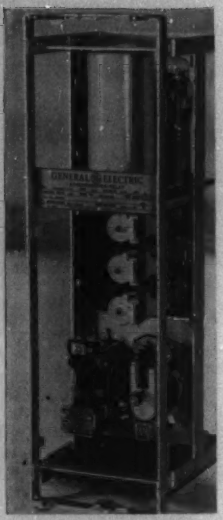


Figure 5. An example of the application of electronics to relays is the electronic synchronizing relay built in 1934 and used widely ever since

popularity is in spite of known limitations of electronic circuits. In other words, the outstanding advantages of carrier relaying outweigh its minor disadvantages.

REQUIREMENTS FOR ELECTRONIC RELAY

If an electronic relay is to compete with an existing electromagnetic device, it must offer advantages, not just novelty. This is particularly evident when the wealth of experience available on electromagnetic relays is considered.

The most desirable improvements over existing relays are in speed, burdens, maintenance, reliability, accuracy, and reduction of the number of contacts. At the present time it is evident that low burdens can be expected with electronic relays and that the operating time can be around one cycle and consistent, being the same at pickup as at many times pickup. This characteristic alone may justify the use of tubes in the protection of transmission lines with ultrahigh-speed reclosing.

The cost of electronic relays depends on their complexity. A simple relay, such as a time overcurrent relay, would be much more expensive than the magnetic version. However, a complex relay, such as a synchronizing relay or a distance relay, may be comparable in cost.

Skepticism with respect to electronic relays is based largely on the contention that radio components are not equal to those normally used in relays. Capacitors and resistors present no problem because the standard relay types can be used. This leaves the tubes and tube sockets. The advent of the new long-life tubes may be the answer to the problem of tube life, but this can be found out only by some years of experience. Tube sockets are available with good contact pressure which would appear satisfactory, but here again a period of experience may be necessary.

In any electronic relay circuit, it is essential that the characteristics of the tube should not control the relay characteristics, otherwise the aging of the tube may change the relay characteristics. However, if the characteristics can be restored by a simple adjustment, which readily can be checked by a simple test, then this requirement may be waived. In other words, if a change of a few per cent in pickup occurs in a period of a year, or when a tube is replaced, and it can be restored by a simple adjustment, this condition may be considered satisfactory.

The effect of transients is an important factor because the operation of an electronic relay depends upon the comparison of instantaneous values of current and potential.

The battery drain should be small, if continuous. Normal variations in battery voltage should not interfere appreciably with the characteristics of the device.

The circuits and their controls should not be so complicated that the ordinary relay test man has to be replaced by a radio engineer.

THE PRESENT OUTLOOK

Two things have tended recently to increase the interest in electronic relays: the advent of long-life tubes; and the necessity for consistent low-operating times, even at low currents, for more effective use of instantaneous reclosing.

Long-life tubes have been developed by tube manufactures in a few forms such as a pentode, a high-mu twin triode, and a low-mu twin triode, all of which are useful in relay circuits.

In reclosing after a fault it is essential that both ends of the section trip within a few cycles of the same time. The inertia of electromagnetic relays tends to make the relays at the end remote from the fault operate more slowly than those at the end near the fault, especially during minimum generating conditions. An electronic tube has no inertia,

Figure 6. Electronic timing meter

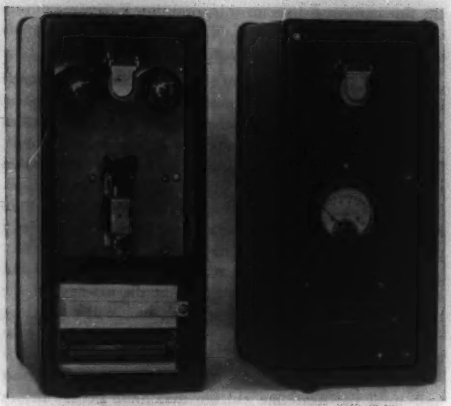


Figure 7. Thyratron pilot wire relay

so that it is possible to design the circuit so that relay operating time is not affected by current magnitude or fault location; consequently both ends of the section can be cleared simultaneously.

While these improvements in components and this need for high speed operation seem to have pointed to the desirability of electronic protective relays, it is not proposed to introduce such relays without first accumulating some practical experience with them.

While electronic relays now can be built to perform nearly any protective function, the question of whether they can do a better job, all things considered, depends upon the application. For instance, the single unit induction cylinder polyphase directional relay is a compact, efficient device occupying about the space of a 4-inch cube. The corresponding electronic relay would involve at least a 6-tube circuit of considerable complexity and, with presently available components, would occupy more space and be more costly. Again, the induction time overcurrent relay sets a standard of simplicity and reliability that would be difficult to meet with an electronic circuit. Finally it is doubtful if any electronic means could effectively replace any of the more common auxiliary relays.

In short, the electronic relay is a valuable tool which has been long appreciated and which has been used wherever it could do a better job than an electromagnetic relay. As improvements are made in the tubes and their accessories, their use will increase and they will be used for new applications where existing relays are inadequate.

THE ELECTRONIC MHO RELAY

To evaluate accurately the relative merits of the electromagnetic and electronic relays, it was decided to build a sample 3-zone electronic mho relay and to compare its characteristics with those of an electromagnetic mho relay. The results were sufficiently encouraging to warrant building a 3-phase terminal which could be put in service on an actual transmission line for a period of operation which would include a lightning season. The selection of the mho relay was based on reasons previously discussed in connection with an early electronic reactance relay, that is, it combines almost all the principles now used in protective relaying. Successful development of the mho relay would imply that little difficulty would be experienced in building some of the simpler high speed relays. (A sample electronic mho relay is shown in Figure 8; a sample electronic timing relay is shown in Figure 9).

Description and Operation. One way to build a relay with a mho characteristic is to compare line voltage with line current at the moment of the line-voltage maximum. A typical unit would consist of three basic elements: a pulsing circuit, a measuring circuit, a tube circuit. This arrangement is shown in block diagram form in Figure 10.

The function of the pulsing circuit is to generate a pulse at the moment of line-voltage maximum. The pulse is used to overcome a large grid bias and permit a tube to conduct. The function of the measuring circuit is to compare the line voltage with the line current. It consists of a transformer supplied with line-to-line voltage and a transactor (defined later) supplied with the corresponding line currents. The secondary of the transactor is provided with a voltage divider which makes possible different impedance pickup settings. An adjustable phase-shifting circuit also is provided to allow the point of maximum reach on the mho characteristic (Figure 11) to occur at different angles.

The tube circuit is the sensitive element which is responsive to signals from both the measuring circuit and the pulsing circuit. The tube circuit also initiates the tripping signal to the circuit breaker when the impedance being measured falls below that for which the relay has been set to operate.

Figure 12 shows graphically the line voltage V, the line

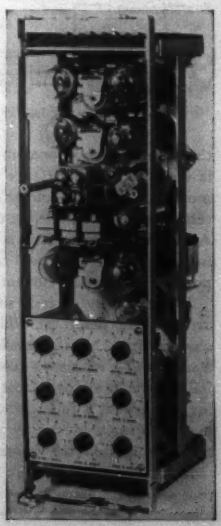


Figure 8. This sample 3-zone electronic mho relay was constructed in order to compare its characteristics with those of an electromagnetic mho relay

Figure 9. Sample electronic timing relay

current I, and related quantities as applied to a typical unit during fault conditions. The pulse (V_p) as generated by the pulsing circuit is seen to occur at the moment of line voltage maximum. The line current (I) is passed through the primary of the transactor in the measuring circuit. A transactor is an air-gap transformer and has a secondary voltage proportional to the primary current. Normally, this secondary voltage leads the primary current by 90 degrees. Actually, it is desirable that this angle be made adjustable by means of a phase-shifting circuit. The dotted wave in Figure 12 represents the shifted secondary transactor voltage. The polarity of the transactor is reversed so that the direction of its secondary voltage will be opposite to that of the line voltage.

In the measuring circuit the line voltage (V) and the voltage proportional to the line current (V_I) are opposed and the combination placed on the grid of a tube in the tube circuit. The direction of the voltage is such that it tends to hold the tube off at the measuring moment (instant of line-voltage maximum) while the direction of

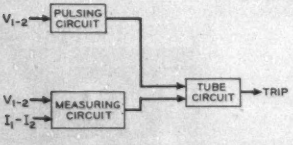


Figure 10. Block diagram showing arrangement of electronic distance relays

the voltage proportional to the line current is such that it tends to cause the tube to conduct at the measuring moment. The line voltage could be considered to have a restraining effect, while the current has an operating effect. A bias in this series circuit is adjusted so that at the measuring moment the tube will conduct when the voltage proportional to the line current just equals the line voltage.

In the appendix, it is shown mathematically that the arrangement described will have a mho-type operating characteristic. It also should be pointed out that, to build a unit with a reactance characteristic (Figure 13), similar basic elements are used, that is, a pulsing circuit, a measuring circuit and a tube circuit. The difference is that the measuring moment occurs at the time of the line-current zero. This also is shown mathematically in the appendix.

Referring again to Figure 12, it can be seen that the current will have its greatest effect when the power-factor angle is equal to the angle between the voltage V_I and the line current I since for this condition V_I is a maximum at the measuring moment. This angle then is the angle of maximum reach on the mho characteristic.

Operating Time. Owing to inertia, measurements made by electromagnetic relays must be made on a rms basis. In electronic relays, on the other hand, no inertia is present and measurements may be made on an instantaneous basis. The use of instantaneous values for measurement makes the electronic relay inherently faster in operating time. The electromagnetic relay must integrate the quantities being compared over a period of time before it can determine the magnitude of the quantity being measured.

Since the electronic mho relay compares instantaneous values of voltage and current only at the moment of the line-voltage maximum, the operating time will depend on the moment in the cycle the fault occurs. This may be understood by considering a fault which occurs at some time after the line voltage maximum. The relay must wait until the next line voltage maximum occurs before measurement can be made. If only a single tube is used, the operating time will vary from 0 to 1 cycle plus the operating time of an auxiliary tripping relay. On the other hand, the use of two tubes reduces the operating time from 0 to 1/2 cycle plus the operating time of an auxiliary tripping relay. One tube would be made conductive at the moment of positive half-cycle line-voltage maximum and the other at the moment of the negative half-cycle line-voltage maximum. Each would have the proper signal from the measuring circuit on its control grid. The operating time is independent of the impedance the relay sees, expressed as a percentage of the pickup setting. This is illustrated in Figure 14.

Burdens. As can be expected with electronic devices, the burdens of the electronic mho relay are very low. Each current circuit burden is less than 2.5 volt-amperes at 5 amperes, and the potential circuit burden is less than 1.5 volt-amperes at 115 volts.

Effect of Transients. Transient shunts are provided to eliminate the d-c component of the fault current wave. Unless the transient shunt is used there is a tendency for the relay to overreach owing to the instantaneous nature of the measurements. When a single tube is used without the transient shunt and a fault occurs near the end of the protected section during the positive half-cycle of the line voltage, there will be negative offset and tripping will be

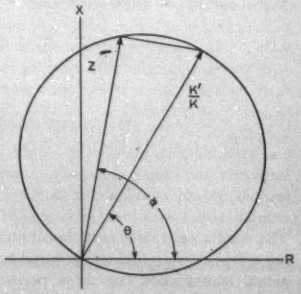


Figure 11. Mho characteristic on R-X diagram

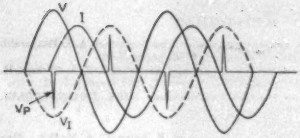


Figure 12. Currents and voltages applied to mho unit

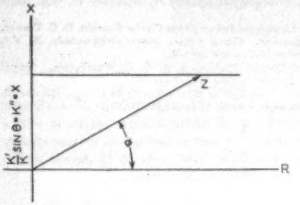


Figure 13. Reactance characteristic on R-X diagram

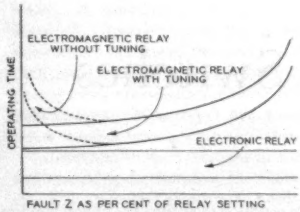

ELECTROMAGNETIC RELAY WITHOUT TUNING
ELECTROMAGNETIC RELAY WITH TUNING
ELECTRONIC RELAY
OPERATING TIME
FAULT Z AS PER CENT OF RELAY SETTING

Figure 14. Time characteristics of electromagnetic and electronic relays

delayed until the offset portion of the current has decayed.

An Electronic Timing Relay. The two time steps required for the 3-zone electronic mho relay are furnished by an external electronic timing unit. These time steps are independently adjustable over a range of 0.05 to 3.5 seconds.

The time delay is obtained by means of the well-known *RC* decay circuit; a capacitor in the grid circuit of a tube normally is charged negatively to a certain fraction of the d-c supply voltage by means of a potentiometer connected across the d-c supply. This setting controls the operating time because the capacitor discharges through a resistor until it reaches the point where its negative voltage is reduced sufficiently to permit the tube to fire.

An important feature of this timing unit is that, unlike most devices using an *RC* timing circuit, its connections are such as to make the operating time practically independent of the variation of the d-c supply voltage.

CONCLUSIONS

Before electronic relays can be accepted in the protective relay field, they must be at least as good as electromagnetic relays in all respects and superior from the standpoint of one or more of the following: reliability, speed, accuracy, burden, and maintenance. Their application also is justified where they can be made to perform functions not possible, or not economically feasible, with electromagnetic relays.

It has been found possible to build a typical high-accuracy electronic protective relay which, laboratory tests indicate, is in every way as good as its electromagnetic counterpart, and in addition, provides faster and more consistent operating time, greater sensitivity, and lower burden. Laboratory tests, however, cannot be considered as the final measure of performance in actual service. Accordingly, plans for comprehensive operating tests on a power system currently are being carried out and, if these tests prove successful, the relay will be made available for application where its superior speed, sensitivity, and burden characteristics are considered advantageous.

In the meantime, development work will continue in order to explore the further possibilities of electronic relays so that when there are applications requiring features which can be obtained better with electronic relays than with electromagnetic relays, the industry will find that they will be available.

Appendix

The operation of the electronic mho relay may be considered mathematically as follows.

Expressions for instantaneous values of the quantities to be compared are

$$e = E_{max} \sin \omega t \tag{1}$$

and

$$i = I_{max} \sin (\omega t + \phi) \tag{2}$$

where e is the instantaneous value of line voltage, E_{max} is the peak value of line voltage, i is the instantaneous value of line current, I_{max} is the peak value of line current, ϕ is the power factor angle, ωt is the angular velocity in radians per second of the alternating current, and t is the time in seconds from a zero point on the voltage wave. In the relay the current is further shifted by an angle θ and both current and voltage are modified by constants K' and K respectively. The bias on the control grid of the relay tube is such that it will conduct when the voltage proportional to the line current $[K'I_{max} \sin (\omega t + \phi - \theta)]$ just exceeds the line voltage as modified by the relay $(KE_{max} \sin \omega t)$, that is, the threshold value is given by

$$KE_{max} \sin \omega t = K'I_{max} \sin (\omega t + \phi - \theta) \tag{3}$$

Expanding the right-hand side of equation 3,

$$KE_{max} \sin \omega t = K'I_{max}[\sin \omega t \cos (\phi - \theta) + \cos \omega t \sin (\phi - \theta)] \tag{4}$$

Considering the moment of the line voltage maximum where measuring is to take place,

$$\omega t = 90 \text{ deg} \tag{5}$$

Substituting in equation 4,

$$KE_{max} = K'I \cos (\phi - \theta) \tag{6}$$

or

$$Z = \frac{K'}{K} \cos (\phi - \theta) \tag{7}$$

which is the polar equation of an mho circle with diameter equal to K'/K. (See Figure 11.)

It has been stated the relay described in this article may be made to have a reactance characteristic by causing the measuring moment to occur at the instant of line current zero. To show that this arrangement produces a reactance characteristic consider equation 2. The line current will be zero when

$$\omega t + \phi = 0$$

or

$$\omega t = -\phi \tag{8}$$

and substituting in equation 3

$$-KE_{max} \sin \phi = -K'I_{max} \sin \theta \quad (9)$$

or

$$\angle \sin \phi = \frac{K'}{K} \sin \theta = K'' \quad (10)$$

since θ is the relay angle and is constant.
Since $\angle \sin \phi = X$.

$$X = K'' \quad (11)$$

which shows that a unit so arranged would have a pickup at a constant value of reactance.

References

1. A Carrier-Current Pilot System of Transmission Line Protection, **A. S. Fitzgerald.** AIEE *TRANSACTIONS*, volume 47, January 1928, pages 22–30.
2. Phase-Comparison Carrier-Current Relaying, **A. J. McConnell, T. A. Cramer, H. T. Seeley.** *ELECTRICAL ENGINEERING*, volume 64, 1945, pages 825–32.
3. Thyratron Tubes in Relay Practice, **Rolf Wideroe.** AIEE *TRANSACTIONS*, volume 53, 1934, October section, pages 1347–53.
4. United States Patent 2,299,501.
5. Carrier-Current Relaying Proves Its Effectiveness, **P. Sporn, C. A. Muller.** *Electrical World* (New York, N. Y.), volume 100, number 11, September 10, 1932, pages 332–6.
6. Pilot Protection by Power Directional Relays Using Carrier Current, **O. C. Traver, John Auchinchoss, E. H. Bancker.** *General Electric Review* (Schenectady, N. Y.), volume 35, number 11, November 1932, pages 566–70.
7. Carrier Pilot Relaying with Distance Back-up, **A. R. van C. Warrington.** *General Electric Company Relaying News*, number 7, June 1937, page 17.
8. A New High-Speed Distance-Type Carrier Pilot Relay System, **E. L. Harder, B. E. Lenehan, S. L. Goldsborough.** AIEE *TRANSACTIONS*, volume 57, 1938, January section, pages 5–10.

Precision Snap-Acting Switches

A. L. RICHE
MEMBER AIEE

FROM THE BEGINNING of the use of electric power, switches have been required for its control, but until recently little attention has been given to reducing their size, weight, and operating energy requirement, except for the work done with mercury contacts. Growth of the use of automatic controls, where mechanical motion is required to open and close electric circuits, has brought demand for units of greater refinement than those typified by the ordinary toggle switch and for freedom from the limitations of tilting mercury tubes.

Diversified use of precision, snap-acting switches began less than 15 years ago and rapidly spread into every type of application where mechanical motion must open and close electric circuits. Their characteristics which differentiate them from other control devices and which give them unique usefulness are outlined in this article.

The first of the family of devices now known as precision, snap-acting switches, made its appearance in 1927, and by 1932, variations of the original device gained commercial acceptance as the contacting elements in thermostats which controlled one-half horsepower oil burner motors, at line voltage, without the use of intermediate relays.

The reliable performance of these switches in thermostats led engineers to try them for other purposes, and it soon was recognized that here was a new tool of versatile usefulness. Growth in the variety and extent of its application has been so rapid that engineers and designers are not completely informed on many phases of the usefulness and the limitations of this newcomer among electric controls.

Essentially full text of paper 48-279, "The Characteristics and Application of Precision, Snap-Acting Switches," recommended by the AIEE domestic and commercial applications committee and approved by the AIEE technical program committee for presentation at the AIEE Midwest general meeting, Milwaukee, Wis., October 18–22, 1948. Scheduled for publication in AIEE *TRANSACTIONS*, volume 67, part 2, 1948.

A. L. Riche is vice-president of the Micro Switch Corporation, Freeport, Ill.

The purpose of this article is to outline the characteristics and the points which must be considered in the use of precision, snap-acting switches.

DIMENSIONS, OPERATING PRINCIPLE, AND CHARACTERISTICS

The dimensions and operating principle of the switch which was introduced in 1932 are indicated in Figure 1, and the characteristics of a typical unit, as now manufactured, are listed in the following:

1. Small size ($1^1/_4$ cubic inches).
2. Light weight (0.8 ounce).
3. Life of millions of operations when used on small loads.
4. Precise repeatability of operation at a given point in mechanical motion of the actuating plunger, maintained for many thousands of operations.
5. Operability by small force (10 ounces).
6. Operability by small motion (0.001 inch).
7. Resistance to the effect of vibration.
8. Capacity to control loads of 20 amperes, at potentials up to 460 volts alternating current.
9. Operability with substantial uniformity when tipped into different attitudes (as distinguished from the performance of mercury switches).

The basic operating principles shown in Figure 1 are used in many variations in size of unit and in operating means, which have been built to meet particular needs. Figure 2 illustrates a few examples of such variations.

There are now several manufacturers offering units which fall into the class of precision, snap-acting switches, some of

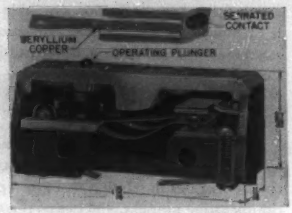


Figure 1. Basic switch operating mechanism

The long spring member is mounted in cantilever. Two short members rest in V's, which are positioned to bow them in compression. The contact, mounted on the free end of the spring, is held against an upper, fixed contact by the couple action of tension and compression forces. When plunger motion deflects the tension member downward, reversal of couple snaps the contact downward. Upon removal of operating force, cantilever action restores the system to its initial position, with snap motion

which are interchangeable in size with those shown in Figure 2. A variety of operating principles differing from those shown in Figure 1 are used, but all employ noble metal butt contacts driven by blade-type snap-acting mechanisms. Spring members usually are made from heat-treated beryllium copper. Most types are self-returning, but maintained contact varieties are available.

In addition to the variations in size, modes of actuation, and operating mechansims, the characteristics of each type of switch are varied to meet the needs of particular applications. The terminology developed for convenience in describing these characteristics is shown in Figure 3.

SELECTING THE SWITCH BEST SUITED TO EACH JOB

The need for care in selecting switches for each application arises from the great variety of styles and operating characteristics which have been produced to meet the range of use-requirements. Two examples will illustrate the breadth of the range.

Among the 300 switches used in the 200-inch Mount Palomar telescope,[1] some operate only in emergencies but must repeat operation within 0.0002 inch of the same point of actuating motion, regardless of changes in ambient temperature or lapse of time between operations. On the telescope, switches are not subject to vibration or impact and the maximum electric load on any switch is a 1/50th horsepower motor. Contrasted with this are switches of the same general appearance, but having different characteristics, which are used on giant punch presses and in rail sanding devices on railroad locomotives. In both of these uses impact and vibration are severe, reliability over many thousands of operations is the prime requirement, and in some cases heavy electric loads must be controlled, but the highest degree of repeatability is not needed.

Repeatability. The gauging operations and control of machine tool motion, shown in Figure 4, illustrate the use of switches where repeatability must be within plus or minus 0.0001 inch in 100,000 successive operations, and must not be measurably affected by normal changes in ambient temperature. When repeatability of this order is required, the operating plunger is carried in a close-fitting guide, and other precautions are taken to insure uniformly maintained point of application of operating force to the snap-acting spring.

Where high repeatability is required, electric loading of contacts must be not greater than 10 watts at 120 volts alternating current or 5 watts at 25 volts direct current. The reason for this is seen in Figure 5, as even moderate

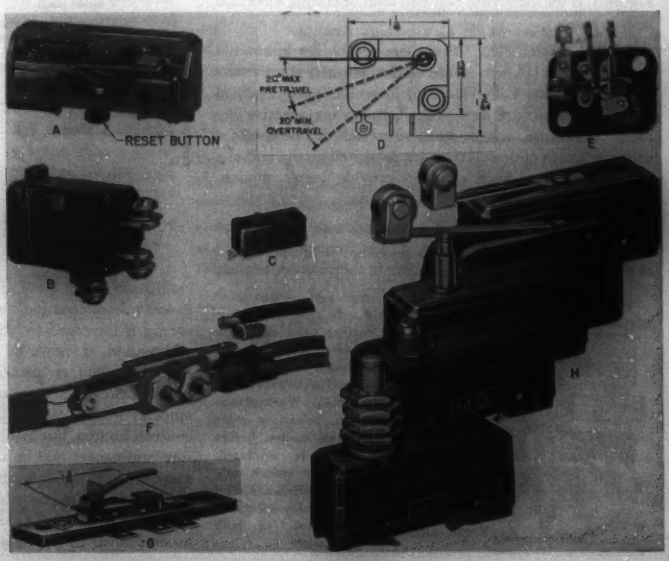


Figure 2. Examples of typical varieties of switch sizes and actuating arrangements

A—Maintained contact type
B—Compact design
C—Subminiature size
D—Rotary actuating motion
E—Mechanism of rotary actuated design
F—Open blade unit with separable, solderless connector
G—Skeleton type
H—Assorted built-in overtravel mechanisms

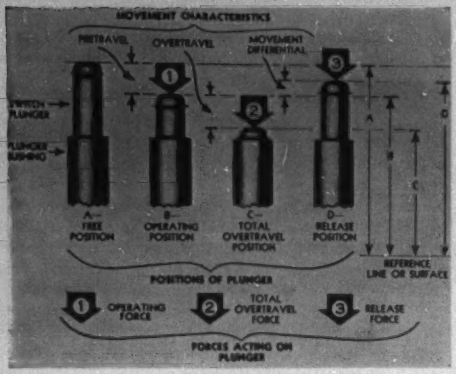


Figure 3. Definitions of special terms

Differential force equals operating force minus release force. Repeatability is stated in terms of decimal fractions of an inch and refers to the maximum variation from a fixed point at which motion of the actuator of a switch causes it to snap over. It usually is specified with reference to a particular number of switch operations, such as 100,000

electric loading of contacts causes sticking which must be overcome by operating motion greater than that required to cause mechanical switch actuation at no load.

Operating Force. The total force required to operate a switch varies from 3 to 28 ounces, depending on the thickness of spring material selected for a given design, and with contact separation. Total operating force is often of less interest than differential force which, as shown in Figure 3, is the difference between total operating force and release force.

Small Differential Force. Switches operable by differential force as low as $1^1/_2$ ounces are used in sensitive thermostats of the type shown in Figure 6, in which partially-filled wafers or bellows are used as the temperature-sensitive element. Likewise, a force-sensitive switch can be used for counting drops of dew as they are deposited on the end of a long lever arm. Such elements provide ample motion, but the available differential force is small.

Small Differential Motion. The expansion and contraction of metals or solid-filled bellows, such as frequently are used as the temperature-sensitive element in thermostats, provide ample force, but the motion available for contact operation is extremely small. Switches designed for use in such instruments operate with a differential motion of no more than 0.0002 inch. This same type of switch is used to detect the deformation of machine parts beyond predetermined limits.

Switch Sensitivity Is Not Synonymous With Precise Repeatability. Repeatability refers to the precision with which a switch operates in relation to a given point in the motion of the operating plunger, and has no relation to the differential motion, differential force, or the product of the two (which is differential energy) required to actuate that switch. Misunderstanding on this point often has led to the specification of switches having unnecessarily close differentials and consequently lower electrical capacity or shorter contact life than can be secured from switches of wider differential characteristics. Precision of repeatability is accomplished by construction which maintains a fixed point of application of operating force to the snap-acting switch blade.

Performance of Sensitive Switches on Large and Small Loads. Switches operable on small loads by mechanical energy on the order of 0.0008 ounce-inch are capable of opening and closing circuit on loads of several amperes at potentials up to 460 volts alternating current, but on such loads operating energy is increased by widening of both differential force and motion, as shown by Figure 5.

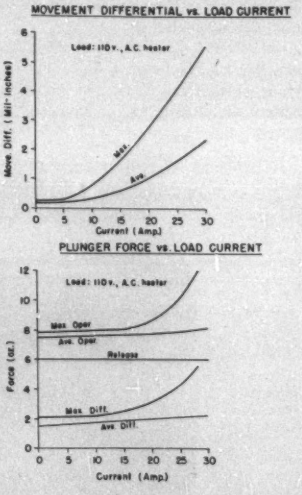


Figure 5. Force and movement differential characteristics

Special contact problems arise when such sensitive switches are used to control loads on the order of milliamperes or millivolts, for not only is initial pressure between contacts limited, but in all switches of this type contact pressure approaches and passes through zero at the instant of snapover. Experience shows that smooth, clean contact surfaces of the purest silver will not close circuit reliably on milliwatt loads. Good performance on such loads is accomplished by use of a serrated contact surface mating

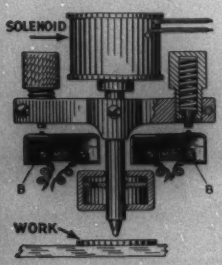


Figure 4. In and out motion of the cutting head on a machine tool is controlled by the switches shown at B. Pieces can be gauged to close tolerance by the switches. Work above-tolerance in thickness stops downward ram motion before either switch is operated. Actuation of one switch only indicates within-tolerance, and a dimension below-tolerance causes operation of both switches

with a smooth-surfaced contact. One form of such serration is shown in Figure 1. This is further discussed under "Contact Materials and Conformation."

Resistance to Acceleration, Impact, and Vibration. High pressure between contacts is necessary, not only for high electrical capacity but to resist the tendency of motion of the entire assembly to jar them apart or into false contact position. Contact pressure can be increased by the use of stiff spring elements, but it also bears the relation to contact separation set out below in terms of resistance to acceleration.

Switch Type	Contact Separation	Resists Acceleration Up to	Probable Mechanical Life (Operations)
Highly sensitive	0.008 in. nominal	35 to 45 G	45,000,000
General purpose	0.020 in. nominal	75 to 80 G	20,000,000
Special wide contact separation	0.070 in. nominal	150 to 200 G	500,000

Switch Life. Switch life, referred to in the foregoing table as "probable mechanical life," represents the median value of the number of operations performed before failure, as determined by a large number of tests.

On small electric loads, life is limited by the mechanical life of the snap-acting mechanism. On heavy electric loads, switch life is limited by disintegration of the contact material or the roughening of contact surfaces to the point where there is danger of sticking due to mechanical interlocking of the roughened surfaces. As indicated in the tabulation, mechanical life varies directly with contact spacings as a result of the necessary spring flexure. Contact life varies so widely with the type of switch and nature of the electric load that no comprehensive tabulation can be set down here. In many instances, however, probable life of 1,000,000 operations or more will be experienced when switches are loaded to their rated capacity.

Switching Capacity and Underwriters' Laboratories Rating. Precision, snap-acting switches are listed by Underwriters' Laboratories under the Special Use Snap Switch Standard. Test procedures and listings under this standard provide only ampere, voltage, and sometimes horsepower ratings. These data are obviously insufficient for use by designers

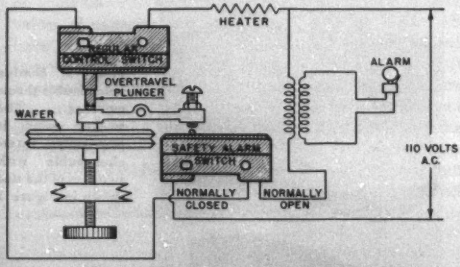
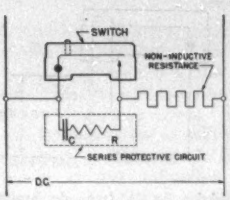


Figure 6. Sensitive thermostat with safety alarm

The wafer operates directly against the main switch but if heat is not cut off by the regular switch, continued expansion moves the lever to operate a safety switch which both takes over control and closes the alarm circuit



Protection for D.C. Heater and Incandescent Lamp Loads

Load in Watts	115 Volts D.C. C (mfd)	115 Volts D.C. R (ohms)	230 Volts D.C. C (mfd)	230 Volts D.C. R (ohms)
0 to 60	0	0	0	0
61 to 160	1/4	0	1/4	2
161 to 230	1/2	1/2		
231 to 500	1	3/4	1/2	1
501 to 750	2	1	1	1
751 to 1000	3	1/2	2	2

Figure 7. Contact protection on d-c loads

in determining the safety of switches on many applications, for they are silent as to the effect of power factor and the inrush current which must be handled on solenoid loads. Horsepower ratings are almost meaningless because of the irregular nature of motor characteristics.

A special section of the National Electrical Manufacturers Association is now writing a standard which is intended to make ratings of precision, snap-acting switches meaningful and a reliable guide to their safe application. It must be remembered, however, that such a standard is a guide only to maximum safe loadings and that there are many uses for precision, snap-acting switches where heavy loading is not compatible with precision of repeatability nor with maximum contact life. On points of this kind NEMA standards and Underwriters' listings are of little value, but switch manufacturers have accumulated much data which are being organized and published.

Paralleling preparation of a NEMA standard, Underwriters' Laboratories has undertaken special tests to determine the safety of certain switches under conditions of operation not covered by any standard and will apply the results of such tests in judging other applications. One such series has been applied to a plastic-enclosed switch, of the size shown in Figure 1, but of different construction, to determine the suitability of the following rating:

Inductive load

Inrush 75 amperes, 460 volts alternating current
Steady state 20 amperes, 460 volts alternating current

Heater load 20 amperes, 460 volts alternating current

Motor load 3/4 horsepower 120 volts alternating current, 1 1/2 horsepower 240 volts alternating current

Lamp load 10 amperes 125 volts alternating current

Maximum permissible continuous ambient temperature 250 degrees Fahrenheit

A rating of this type is based on the experience that interruption of an a-c load of any kind is not the limiting factor, for within the voltage rating there is never any difficulty with extinguishing the arc. For example, on tests to establish the foregoing rating, full inrush current of 75 amperes at 460 volts and at 35 per cent power factor was interrupted repeatedly with no arc persistence. This is distinguished from the effect of such loading on contact life.

Underwriters' Snap Switch Standard specifies a temperature rise of 30 degrees centigrade above normal ambient as the rating limitation. This has been shown to be unnecessarily low when silver contacts are used[2] and spring

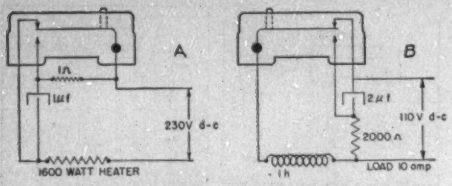


Figure 8. Special contact protection for (A) large d-c heater loads and (B) large d-c inductive loads

elements are of beryllium copper or other material which retains its characteristics at high temperature.

The afore-mentioned permissible continuous ambient temperature rating is determined by checking switch performance over 100,000 operations, under full electric load, during a 90-day period, while exposed to the rated ambient temperature.

The factors limiting switch ratings are: welding together of contacts on heater loads, and contact life on inductive loads. The reason for this limitation on heater load rating is that, unless special precaution is taken to prevent it, contacts come together with a bouncing motion and the resulting arc melts contact materials which cause a certain degree of welding together of contact surfaces. On a heater load full current flows in the arc from the very beginning of the first bounce, whereas on inductive loads, such as motors or solenoids, full current does not build up until after the period of bounce is passed. The time during which high inrush persists on such loads is so short that inrush current many times the value of permissible steady state current can be handled satisfactorily. The same is true of a tungsten lamp load, for a lamp which draws 10 amperes after equilibrium is reached permits an instantaneous inrush on the order of 125 amperes when the filament is cold.

CONTACT MATERIALS AND CONFORMATION

Fine silver contacts satisfactorily serve most purposes. However, smooth silver contacts, even though perfectly clean, cannot be depended upon for reliable closure of circuits on either a-c or d-c loads of the order of millivolts or milliamperes. Satisfactory performance, however, has been accomplished in switching thermocouple circuits and on minute a-c loads in aircraft circuits, by use of a fine silver serrated contact working against a smooth silver surface. Such a surface is shown in Figure 1. This success is attributed to increased unit pressure, as compared with that existing between smooth contact surfaces, the establishment of multiple contact points, and reduction of the probability of minute specks of foreign material holding contact surfaces separated. It is also probable that the knifelike edges of serrations cut through surface film on the smooth mating surface as the two come together with wiping motion. Tests of the performance of this contact arrangement have included introduction of fine dust of insulating material which causes immediate failure of smooth contact surfaces. Exposure to humidity and an atmosphere of sulphur dioxide has shown marked improvement in performance of serrated contacts, as compared with smooth-surfaced contacts. The good showing of the serrated surfaces under these tests is supported by many years of satisfactory field service under conditions where smooth contacts previously had given a great deal of trouble.

Since it is desirable to use one form of contact for the widest practical range of applications, field and laboratory testing has been undertaken to determine the suitability of the serrated contact for use on heavy, as well as extremely small, loads. The results of these tests have shown serrated contacts to be generally useful.

Contact Materials Other Than Silver. Pure silver is not the ideal contact material when electric loading is such as to produce splash, which so contaminates insulating surfaces as to invite flashover. On d-c loads silver tends to transfer from one contact to the mating surface in the form of a peak and crater, and on all loads above a few watts there is some degree of sticking. All of these deficiencies stem from the low melting point of silver, and most attempts to remedy them are directed at so alloying silver as to retain its desirable features of high electrical and thermal conductivity and resistance to the formation of nonconducting surface film, and at the same time raise its melting point. Among the many proprietary silver alloys available, those containing copper, nickel, iron, and cadmium oxide have been found most useful in precision, snap-acting switches. There is not yet enough experience to justify general recommendations, but there is reason to believe that improved contact performance on some specified loads can be accomplished by selection of a contact alloy suitable to each.

USE ON D-C LOADS

This type of switch was designed primarily for use on alternating current, but direct current applications constantly arise. Millions of such switches have been used on 30-volt d-c aircraft applications on loads up to 25 amperes. Most switches for such use have contact separa-

Figure 9. Double pole, double throw switches. The smaller switch is physically interchangeable with switches of the size shown in Figure 1

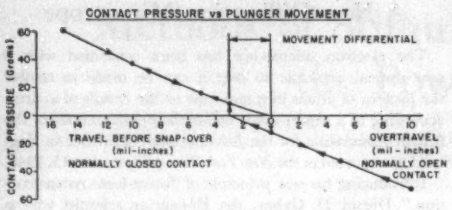


Figure 10. Contact pressure characteristics

tion of 0.070 inch, which separation is necessary to insure circuit interruption without sustained arcing, particularly at high altitudes. In general no special arc-snuffing circuits are used on such low-voltage installations. On heavier aircraft loads, particularly where the frequency of operation is high, a special form of switch is used in which the arc is blown out by a permanent magnet.

Noninductive Loads. On d-c heater loads up to 60 watts at 115 and 230 volts, no contact protection is required. The circuit and values of capacitors and resistors to be used above that loading are shown in Figure 7. Use of this circuit not only insures snuffing of the arc but minimizes the transfer of contact material, which is always a serious problem on d-c loads. On loads above seven amperes at 230 volts, the circuit shown in Figure 8*A* is often effective. It has the particular advantage of being noncritical.

Inductive Loads. The switching of d-c loads, where even a moderate amount of inductance is present, introduces problems, many of which can be solved only by cut and try testing. There is no means for accurate, advance calculations of the performance of such circuits, and the usual procedure is to try various combinations of capacitors and resistors, connected in the circuit shown in Figure 7, and observe the character of the arc formed between switch contacts. Experience develops ability to judge when the best combination has been found, but in many instances extensive tests are necessary to supplement that judgment. In many instances the circuit shown in Figure 8*B* is found more useful than others, particularly on loads above those set out in the table of Figure 7. The values of capacity and resistance, shown in Figure 8*B*, have been used successfully on the load there indicated, but, as mentioned in connection with the circuit shown in Figure 8*A*, these values are not critical as are those shown in Figure 7 and may be used on loads varying materially from those indicated. The theory of the operation of this circuit is not well understood, but experience has shown it to be effective as an arc-suppressor. It does not, however, inhibit the transfer of contact material as well as the simple combination of capacity and resistor connected across the switch contacts.

DOUBLE-POLE DOUBLE-THROW SWITCHES

Most precision, snap-acting switches are of the single pole variety. There has, however, been an ever-increasing demand for double pole construction, particularly for use on aircraft and by the Signal Corps. The types developed during the war have not been entirely acceptable because of their size and weight. This is shown full scale in Figure 9, together with a new unit which is interchangeable in size with the commonly-used single pole switch. See Figure 1 for dimensions. This new unit provides for simultaneous action of both poles in each direction, with sustained positive pressure between contacts up to the instant of their separation. This is accomplished by simultaneous application of hammerblow action to both current-carrying members by a separate snap-acting mechanism.

PRESSURE BETWEEN CONTACTS

Figure 10 illustrates the change in pressure between contacts as the operating plunger moves through the operating differential. This shows that as the snap point is approached contact pressure approaches and passes through zero. When the speed of operating motion is greater than about 0.001 inch per minute, this type of operation has proved to be entirely satisfactory for the great majority of uses, particularly when the switch is not subject to vibration. Difficulty is experienced, however, where the mechanical drive is extremely slow or where the operating plunger of the switch normally is held near the operating point most of the time, as in thermostats. The difficulty is exaggerated if the switch is so mounted as to be vibrated synchronously with the power supply, as, for example, by the vibration of a motor or by air pulses from a fan. In such an assembly the switch is moved bodily in one direction on one-half of the cycle and in the other direction on the second half. Inertia of the moving contact tends to hold it stationary which results in the switch acting as a rectifier. Under such conditions the contacts rapidly deteriorate due to arcing on the half-wave rectified current. When it is not practical to avoid such synchronous vibration, switch contacts can be so mounted as to sustain positive contact pressure up to the instant of separation.

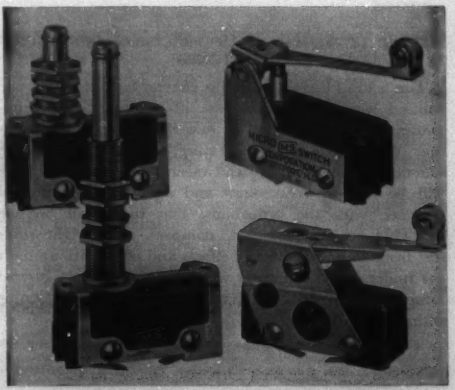


Figure 11. Bracket overtravel actuators

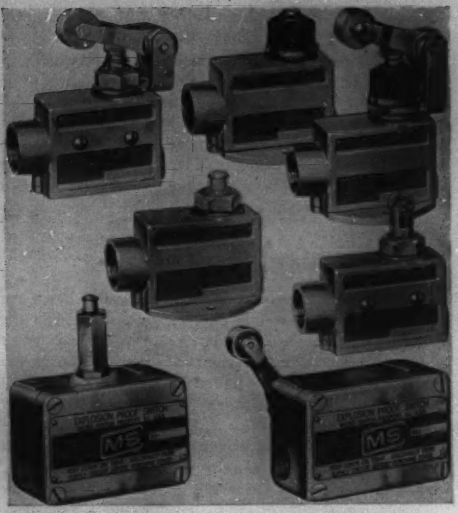


Figure 12. Protective housings and overtravel actuators

AUXILIARY ACTUATORS AND HOUSINGS

For many uses the mechanical motion available for operating switches is either so wide or so lacking in uniformity as to make its direct application to precision snap-acting mechanisms impractical. Overtravel devices necessarily must be introduced to absorb the excess or variable operating motion. Some of the mechanisms available as parts of basic switches are shown in Figure 2. Others are made portions of special brackets, or of the metallic housings which are required for protection of basic switches against mechanical damage, oil, coolant, water, or corrosive or explosive atmospheres. Figures 11 and 12 give examples of these enclosures and overtravel actuators.

FUTURE DEVELOPMENT OF PRECISION SNAP-ACTING SWITCHES

The field of usefulness of this general type of switch will expand with ever-growing use of automatic and semi-automatic mechanization of manufacturing, merchandising, the control of temperature, humidity, and such functions as the lowering and raising of windows. These will be met by refinements and adaptations of present switches, with the probability that there will become available completely-sealed, compact, lightweight units free from all environmental effects and filled with an inert gas under such pressure as will adapt it to direct current as well as alternating current use, in a manner not attainable with present designs.

REFERENCES

1. Electrical Features of the 200-inch Telescope. *ELECTRICAL ENGINEERING*, February 1942, pages 67–78.

2. Suggested Changes in Temperature Limits of Present Standards for Stationary Contact Surfaces. *ELECTRICAL ENGINEERING*, March 1948, pages 253–57.

A New Diffraction Microscope

The electron microscope has been combined with a new optical principle so that it can be made to resolve the pattern of atoms in a molecule or the details of a virus, according to a report made before the physics section of the British Association for the Advancement of Science in England as reported in the *New York Times*, September 15, 1948.

Introducing his new principle of "wave-front reconstruction," Doctor D. Gabor, the Hungarian scientist who is specializing on the project for the British Thomson-Houston electrical engineering concern, said that the electron microscope has reached the technical limit of resolution at about five angstrom units. Though this is about 200 times better than the best ultraviolet microscope, it is still 200 times worse than would be the case if the magnetic lens of the electron microscope could be made as perfect as optical lenses, the limits of which are imposed by the wave lengths of light.

The new device, called the "diffraction microscope," gets around this difficulty by a 2-step process. In the first step, an electron photograph called a "hologram" is taken. In the second step, the likeness is restored by a reconstruction or synthesis carried out with light waves.

The beam of electrons in the microscope is reduced to pinhole dimensions by a series of lenses which, though imperfect, do not destroy the coherence of the beam. The beam produces a diffraction picture of the object. This, the "hologram," is transferred to an optical system in which the aberrations of the electron beam are exactly reproduced but in terms of light waves scaled to the ratio of the electron waves, about 100,000 times.

The second source is a pinhole of monochromatic light, which illumines the "hologram" and resolves the diffracted picture into an image which is at least as clear as the earlier radio pictures.

This new method would go far towards removing the burdens and limitations now imposed upon scientists and scientific research by the X-ray microscope, Doctor Gabor stated. It would reduce to a fraction of their present number the observations necessary to obtain the atomic pattern of a molecule. It also would bring into definition viruses and other micro-organisms which, up to the present and with the types of microscopes now in use, only have been hinted at in researches so far. This new "diffraction microscope" also would reduce considerably the amount of time consumed for the necessary observations.

Even with this new principle, Doctor Gabor warned, scientists would still not be able to see an atom. Such minute detail is beyond the scope of existing magnifying apparatus, and is still the object of much study by researchers and scientists.

The electron part of the "diffraction microscope" remains in the paper and planning stage. The major obstacle to its perfection and completion is the engineering problem of producing the pinpoint beam necessary for successful operation of the device. Doctor Gabor, however, demonstrated the optical part before the physicists attending the meeting, convincing them of the validity of the "wave-front reconstruction" principle.

Methods of Stimulating Teaching in the Power Field

E. W. BOEHNE
FELLOW AIEE

The student trained in the wide-band frequencies will bring more to the power industry than the student trained in 60 cycle alone. To attract the student to the power industry, he must be shown that new and challenging frontiers exist. One of the first steps in the program recommended is the creation of a list of challenging thesis subjects to guide the student to the door of the power industry.

PERHAPS the first endeavor for the power interest should be to undertake the creation of a Pied Piper whose magic will coin a new word to replace the overused title, "power." He might come up with such alluring titles as "poweronyx" or perhaps "megatronyx" and draw a following to that field which we know today by the word, power.

The primary need today in the field of power is an inspired leadership. The problem is largely a mental one. It is concerned with how the student envisions himself at work following graduation. He now is enamoured with the romance of radar and television. He is influenced tremendously by the goals of his associates. He is afraid of missing something if he does not follow the stream. These trends and ideals are set early in his school career. Fortunately the vast majority of collegiate curricula are designed to give the student common engineering subjects through the first year and should he enter electrical engineering he again gets a dose of the common denominator subjects in the electrical arts. By this time he has been around long enough to evaluate the situation and, we hope, direct his attention toward goals he finds interesting and profitable. Should he still linger in the dreams conceived for him or by him before he was armed with all the facts, there is still hope. Contrary to an often expressed opinion, I differ in the viewpoint that the electronic fields present serious competition with the power interest. The lines of demarcation in the training for the field of power as compared to the training received in the communication and electronic subjects is by no means as sharp as many outside educational circles are led to believe. All receive essentially the same fundamental curricula in engineering prior to their senior and graduate years. Moreover, the training in the wide band of frequencies as afforded the communication student, in the long run, will bring more to the power industry than men trained in 60-cycle phenomena alone. Indeed, the power industry already has felt the impact of the electronic wave and will continue to wade in its expanding precepts for some time to come.

THE ENGINEER'S TRAINING

On the simple premise that the engineer is responsible for the conversion of the discoveries of research into the products and "know-how" of industry, it follows that he should have, and maintain, a broad knowledge in closely allied fields in order to be able continuously to comprehend the results of research. Fundamental training in the wide band of frequencies, not to the exclusion of 60 cycles, however, is an important foundation block upon which he can maintain this vigil.

It is at this point that two significant trends appear on the horizon. The alert communication and electronic staffs are not overlooking their obligation to the lower end of the frequency spectrum but instead emphasize the phenomena at 60 cycles. This trend has permitted the suggestion that the classification of subjects into the options of power, communication, and electronics be eliminated completely and that all electrical students be so grounded in the fundamentals as to permit their moving in any direction depending upon the particular demand at the time of graduation.

This goal, if accomplished, re-emphasizes the teaching of fundamentals. Of primary importance, it removes at least half of the psychological boundary which blinds the student toward a goal he chose when under the influence of immature knowledge of his ultimate opportunities. One common ground for streamlining the curricula lies in the principle of energy transfer. The d-c machine and the vacuum tube are both modulators of power flow. The presentation of the performance of systems as a whole, the calculus of system behavior, and allied subjects, are of value to all students regardless of their ultimate employment. Such fundamental studies come in enlightened courses in servomechanisms and the teaching of rotating machinery as energy conversion devices. Communication theory which includes the fundamental behavior of lines at 60 cycles will be of significant help. Transient theory already is so formulated that its precepts are applicable to all electrical problems. Here again the common denominator of energy is the binding feature.

The trend toward a fixed program through the third year might be counterbalanced by greater flexibility in the senior and graduate years. The senior who intends to complete his work with a bachelor of science degree can have wide freedom of electives to prepare for the field of his choice. If a graduate year is planned he may have to con-

Full text of a conference paper presented at the joint conference on education and Student Branches held during the AIEE Midwest general meeting, Milwaukee, Wis., October 18-22, 1948.

E. W. Boehne is associate professor of electrical engineering and director of a course in co-operative education in electrical engineering at the Massachusetts Institute of Technology, Cambridge, Mass.

centrate on special prerequisites of graduate courses. Flexibility should be the keynote of the senior and graduate years.

Already the importance of labor, industrial relations, finance, marketing and reports, manufacturing technique, quality control—all in the department of business administration—are finding acceptance for graduate study in preparation for entering the power field. This trend is most notable among electrical engineering students participating in the co-operative courses in electrical engineering where they have the opportunity to see at first hand the requirements of industry.

The utility which places security first on the list of employment benefits and obtains predominantly the youth who first seeks security, places a premium on mediocrity. The American youth today still possessing our traditional pioneer spirit, is seeking new frontiers. They are finding many of these frontiers in the unsolved problems and developments in the "wide band" sciences, servo systems, atomic physics. It follows that the power industry must match this urge, not because of the competition, but by a genuine participation in a critical review of its problems. Unless the power interest can demonstrate in a vivid way that new frontiers do exist at the 60-cycle level, that there is a place for the student who leans toward electronic fields, that the frontiers are not closed, it will have to be content with the development of new administrative personnel from the non-engineering graduates.

NEED FOR INDUSTRY SURVEY

No small part of this development program consists in a reawakening of the electrical engineering staff with the nature of the power industries' "frontier" problems. This step is important as a source of thesis material for the power man. Moreover, the fact that every staff member is a student advisor, whose opinions are heeded closely, emphasizes the importance of this step in the scheme of student placement. I plead in particular that power's problems not be relayed alone to the so-called "power staff," but to the entire electrical engineering staff in order to give balance to the relative merits of all opportunities. Pending the acceptance of a streamlined engineering curriculum for all engineering students through the third year, it follows that blanket staff education becomes imperative. In fact, such a move might be genuinely prerequisite to such curriculum and unquestionably speed its adoption. To do this requires, in most cases, that the power interests review critically and searchingly their own needs and problems. Vision, and skill, and a creative outlook are essential to such a critical review. An inaccurate appraisal of the situation would lead to early failure.

The channels of the AIEE organization offer an ideal medium for the engineering of such an industry survey. If each technical committee fringing on the power interest created a subcommittee for the express purpose of critically reviewing their field, outlining the frontier problems with imagination, preparing a list of these suggestions, and publishing their report in a special section of *ELECTRICAL ENGINEERING*, the following would be accomplished:

1. The impartial source of such a mass presentation would draw immediate attention in every institution.

2. The power student could consult an approved, authoritative list of live theses and seminar suggestions which not only would augment his own immediate needs, but a review of the problems en masse would have immeasurable value in assuring him that the power industry did offer interesting technical frontiers.

3. Such a seeding is needed urgently and a planting at this time will take many creative forms in the minds of the alert staff. Such staff stimulation unquestionably must reflect in student enthusiasm and attitude.

4. Healthy competitive thesis participation on the part of several students in various institutions can develop as a result of the parallel attack on identical problems. Papers based on outstanding theses can find their way before student and District meetings.

5. Aside from creating interest on the part of the student, a challenging thesis will serve to demonstrate to the prospective employer the student's ability, initiative, and industry in tackling and solving a specific task. A review would show that many men pursue careers initiated by their thesis study. Their interest in their initial industrial assignment would be stimulated. Of more importance, their basic attitude toward the industry would be improved.

6. The stimulation of student membership and enthusiasm in the AIEE would be a natural development. At joint AIEE-Institute of Radio Engineers student meetings selected staff could augment the suggested thesis titles with their personal interpretations and suggestions. Students at the freshman and sophomore levels could redirect their interests. The student no longer would ask that first question, "What would I get out of joining the AIEE?"

The carrying out of such a program in an effective manner is not easy. Courage, co-operation, and creativeness are essential prerequisites. A competent member of the graduate school of recognized universities and institutions, particularly one specializing in the field in question, could be of assistance on such committees in formulating the suggestions in such a manner as to be acceptable for academic pursual. The rewards of such a dynamic gesture on the part of the power industry in co-operation with the AIEE would go a long way toward paving the road toward the goals and objectives which have been outlined. Everybody profits.

THE OBJECTIVES

The following salient objectives are recommended: Inspired leadership to guide the student in studies of fundamental principles and fundamental concepts, including the "wide band" of frequencies, all augmented with the latest tools of mathematics and circuit theory; demonstrated in the presentation of a challenging problem of research or development in the form of a well written thesis which leads the good student enthusiastically to the door of an industry which emphasizes the challenge of the future, rather than the romance of its past, and which will fulfill its obligation by rewarding individual service, encourage the pursual of advance studies, participate in some creative work under its own roof, and continue to keep the staff and students of its neighboring educational institutions aware that new frontiers are always open to the wide awake and aggressive student.

In turn the colleges will work toward the creation of good, cost conscious power engineers whose hobbies include "electronyx" and labor relations, who can write a good report, speak so they can be heard at the back of the room, and be understood by those in the front row.

Reversing Cycle of Modern Blooming Mills

T. B. MONTGOMERY
MEMBER AIEE

J. F. SELLERS
MEMBER AIEE

TODAY THE D-C MOTOR with rotating regulator control is the accepted modern standard blooming mill drive in the metal-processing industry. By studying a typical blooming mill with a d-c variable-speed motor drive rated at 7,000 horsepower, 40/100 rpm, 700 volts, and by comparing it with the equivalent ratings in single speed motors, the variable speed one can be justified.

For the rapid reversal of a mass of large WK^2 value, such as that of a blooming or slabbing mill, a drive which would apply constant torque over the complete cycle of full speed forward to full speed reverse and vice versa, might, at first sight, appear desirable. For the electric drive of such load, a single-speed d-c motor could be used with variable voltage control, speed reversal being accomplished entirely by generator voltage. With present-day methods uniform acceleration with current limit control could be accomplished with relatively simple equipment. However, from the electrical point of view such a drive is inefficient in that it uses only one-half of the peak available horsepower.

Field weakening control utilizes a greater percentage of average horsepower. The 7,000-horsepower motor under study with a speed range 40/100 rpm and giving $2^1/_2$ times the torque per ampere at base speed as at 100 rpm, provides the margin needed for initial passes where large reductions are required and for special alloys or "cold" ingots. This choice is the most economical for the job.

Accepting the control complications involved by this selection, calculations are made for the ideal desired reversing cycle. These calculations determine the theoretical excitation, control, and power characteristics necessary to attain the desired results. The major problem in controlling the variable speed drive accurately is occasioned by motor field weakening. If the motor field flux is not increased at the proper rate, counter electromotive force and decelerating current may rise sharply to high peak values which may affect commutation adversely and put undue strain on equipment. Step-by-step calculations are necessary to determine the theoretical reversing cycle.

Control for the typical installation is provided through Regulex exciters controlling both the motor and generator fields, with reference field provided from a constant potential source through the mill master. From theoretical calculations the peak voltage of the motor and generator exciters is beyond practical limits for both economical size and rate of response, so a compromise can be made with a 250-volt nominal rating on the exciters. The flux density is kept low to provide quicker response and good control.

In practice, the theoretical reversing time of 4.55 seconds has been reached but in doing so the accelerating current was not held constant. In some installations it has been found that such a short time cycle could not be utilized because of the time required by approach tables, manipulators, screwdowns, and so forth. At the present time a reversing cycle of approximately seven seconds seems most practical. This would call for overlapping of generator and motor field control, reducing the initial decelerating current to 50 per cent instead of 75 per cent. Summarizing the analysis we have found that:

1. It is possible to predict by calculation close approximations of current and voltage values during the reversing cycle.

2. By proper selection of exciter voltages and the use of rotating amplifier-type control, a shorter reversing time is possible than previously was accepted as satisfactory.

3. By close attention to the factors in machine design affecting the time constants, including laminated frames of main motors, generators, and exciters, a still shorter reversing time is possible and problems effecting commutation are made easier.

4. A shorter reversing time requires faster operation of auxiliaries as approach tables, manipulators, screwdowns, for over-all gain.

5. It becomes an evident fact from the data that a practical reversing mill control must have exciters with a voltage range 250–300 per cent greater than the required IR field voltage. Laminated construction would reduce this forcing voltage requirement about 25 per cent.

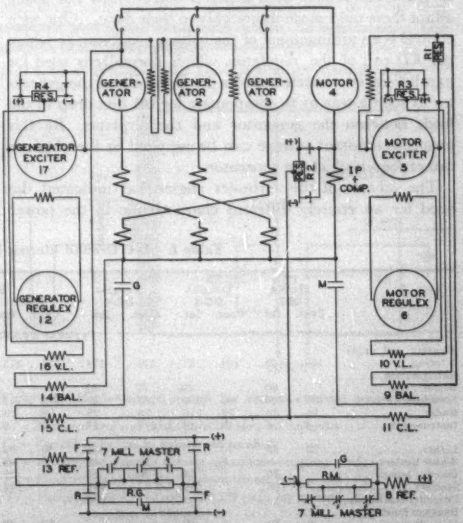


Figure 1. Simplified diagram of a reversing blooming mill control

Digest of paper 48-271, "The Reversing Cycle of Modern Blooming Mills," recommended by the AIEE mining and metal industry committee and approved by the AIEE technical program committee for presentation at the AIEE Midwest general meeting, Milwaukee, Wis., October 18–22, 1948. Scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

T. B. Montgomery and J. F. Sellers are both with the Allis-Chalmers Manufacturing Company, Milwaukee, Wis.

Ground Power for Aircraft

JOHN H. BLANKENBUEHLER
FELLOW AIEE

COMMERCIAL and military aircraft have outgrown the days when they could be supplied with electric power while on the ground from a small box of batteries. As may be seen from Table I, the power requirements of an airplane on the ground have risen until this power is measured in thousands of amperes.

Because the airplane is not always at a fixed position when on the ground, the most popular source of this power has become a gasoline-engine-driven generating unit with special controls for providing the characteristics desired. These units now are being built with ratings from 200 to 2,000 amperes. They also are being built with various types of running gear, some of them being self-propelled while others are arranged as trailers or have small wheels and are to be pushed to various locations by the ground personnel.

Except in the smallest sizes, the generators are separately excited and the most common varieties are controlled by the standard aircraft-type voltage regulator to give a constant voltage output. The most common voltage is 28.5 volts. Many of these units perform a multiple service by carrying floodlights which are supplied with power from the exciter of the main generator. All of them also carry carbon dioxide fire extinguishers of various sizes. Some of the self-propelled units also are arranged so that they can be used to tow baggage carts and airplanes.

Whereas most of the controls on these outfits are ordinary, several features have been added which are new and which adapt these units more thoroughly to their duty. One such control is an arrangement of the voltage regulator, in which the *KD* coil of the regulator, which normally is used for paralleling, is connected across the field coils of the generator in such a way as to compensate for the line drop in the leads between the generator and the airplane. By this means, a constant voltage can be supplied in the airplane rather than back at the generator.

The advent of the turbo-jet engine has indicated the need for an entirely different characteristic in the power unit used to start these engines. In this case, it is desirable to have a generator which will supply a perfectly constant current to the starting motor and which will be connected automatically to the starting motor at zero voltage, then build up its voltage and maintain the predetermined constant current until the predetermined maximum voltage is reached. After the maximum voltage is reached the current then decreases to a predetermined value and automatic devices disconnect the generator from the turbo-jet starting motor. A very simple system for securing this constant current characteristic has been worked out using one of the conventional aircraft-type voltage regulators with a special very low resistance coil on it which can be adjusted for voltages in the order of one to two volts. By connecting this coil across the field coils of the generator this regulator will function to maintain a constant current output of the generator. In addition to this constant current regulator the ordinary constant voltage regulator is also in the circuit. A generator with this type of control minimizes the starting shock on the starting motor and its gears and thus permits the lightening of these devices.

Another problem with this type of generating unit is the suppression of radio interference. This requires the filtering, by means of capacitors and suppressing resistors, of the battery charging and ignition systems of the engine as well as the main generator and exciter.

Interesting, also, are mechanical problems which become almost as varied. A motor-driven generating set, for instance, must have controls arranged so that any contact which might create a spark are over four feet from the floor. This is done to prevent any explosion of vapors which might collect on the floor.

Digest of paper 48-240, "Ground Power for Aircraft," recommended by the AIEE air transportation committee and approved by the AIEE technical program committee for presentation at the AIEE Middle Eastern District meeting, Washington, D. C., October 5–7, 1948. Scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

John H. Blankenbuehler is engineer for Hobart Brothers and Motor Generator Corporation, Troy, Ohio.

Table I. D-C Ground Electric Loads in Amperes at 28½ volts

	Martin 202		Douglas DC-4		Douglas DC-6		Boeing 377 Cold		Boeing 377 Hot		Boeing 307		Consolidated Convair		Lockheed Constellation		Military	
	Cont.	Int.	Cont.	Int.	Cont.	Int.	Cont.	Int.	Cont.	Int.	Cont.	Int.	Cont.	Int.	Cont.	Int.	Cont.	Int.
Heating and ventilating	109	109	121	121	174	174	215	215	120	120	17	17	3	19	279	279		18
Refrigeration									880	880								
Buffet		60		60	67	67												
Inverters	105	105	90	100	95	95	315	315	315	315			126	126	650	650	91	91
Radio	14	22	78	118	28	28	30	30	30	30	20	38	20	37	87	87	21	108
Instruments	4	5	10	10	17	17	6	6	6	6	14	14	14	14	55	55	3	3
Lights	33	33	70	70	185	185	60	60	60	60	40	40	53	53	80	80	2	2
Water heaters					30	30	44	44	14	44					86	86		
Booster pumps		20		15	20	20		15		15			50	50	50	50	7	7
Starters		198		198		198		240		240		183		175		175		276
Propeller feathering						200						147	6	153	20	170		
Baggage hoist																178		
Miscellaneous	6	12	6	10			20	40	20	40			7	7				
Total	271	564	375	702	616	1,014	690	965	1,475	1,750	91	439	279	634	1,307	1,810	124	505

Radio Influence From High-Voltage Corona

GORDON R. SLEMON
ASSOCIATE AIEE

This article is the result of a study made in the field of high-voltage power transmission to obtain information regarding radio-frequency propagation which may be expected from corona. Numerous experiments have been made to determine the conditions under which these radiating impulses occur.

IN THE STUDY of high-voltage power transmission, corona phenomena have received considerable attention. The power loss which accompanies corona has been investigated to the extent that general prediction may be made under most conditions. The increase in the voltage level of long-distance transmission lines coupled with the extension of communication facilities has created a demand for a more adequate knowledge of the radio-frequency propagations which may be expected from corona.

The experimental work of this project has been directed toward two main objectives. The first of these is a clarification and extension of the basic concepts of the space-charge phenomena which occur in corona. The general conditions under which radiating impulse currents will occur have been described and an attempt has been made to show the effects of some of the variable factors. From the observations, certain additions and clarifications have been made in corona theory. With the aid of this firmer theoretical background, a beginning has been made in the field of radio-interference control under various voltage conditions.

EQUIPMENT

Because of the sensitive nature of the field measurements necessary in this corona study, the equipment was installed in a radio-frequency-shielded cage. This cage was ten feet square, eight feet high, and of standard construction with wire mesh on both inner and outer walls.

Power Supply. Supplies of 25, 60, and 500 cycles per second power at 110 volts were brought into the cage through radio-frequency suppressors. Transformers were installed to supply continuously variable voltages up to 50 kv at all three frequencies.

Conductor Plane Configuration. Separation of the effects of positive- and negative-potential corona discharges was accomplished by the use of a single conductor mounted parallel to a grounded plane. The electric field produced about this conductor is identical with that about one conductor of a two-conductor single-phase transmission line with double the conductor-to-plane spacing and operating at double the voltage.

Most of the tests were made on a number 8 smooth solid conductor as this was the largest diameter which the 50-kv power supply would allow.

Bridge for Corona Current Measurements. To separate the corona current from the capacitive charging current of the conductor a simple capacitance-resistance bridge, as shown in Figure 1, was constructed using the conductor plane as one capacitance arm.[1] The bridge was balanced at a voltage below corona threshold. Above the threshold voltage, the detector voltage is a measure of the corona current.

Measurement Equipment. High- and low-frequency radio noise meters were used for comparative measurements of the corona radio noise. Inside the cage, the induction field predominates. As there was some doubt of the accuracy of a rod-antenna instrument in this field,[2] no quantitative measurements of radio noise were made. A communications receiver was fitted with a probe antenna for use in radio-noise location. For measurement of the intensity and phase of the audible corona discharge a sound-level meter with microphone was employed. As well, it was thought advisable to analyze the visible spectrum radiations from corona. The output of a photoelectric cell was amplified with provision for differentiation, in order that constant and pulse radiations might be separated. The outputs of all measurement devices could be applied to the plates of a double-beam oscilloscope for comparison.

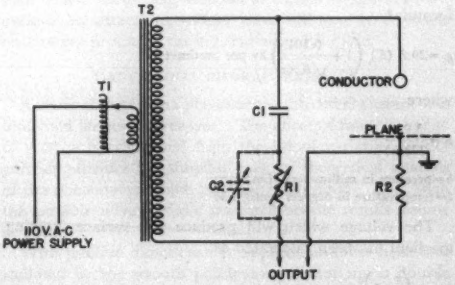


Figure 1. High-voltage circuit for corona current measurements

C1 = 20-microfarad 50-kv parallel-plate air capacitor
C2 = Variable capacitor to balance out residuals
R1 = Variable resistance to balance capacitance-resistance bridge
R2 = Fixed resistance in capacitance-resistance bridge
T1 = Variac—primary: 110 volts, 25-500 cycles per second
secondary: 0-135 volts
T2 = High-voltage transformer—primary: 110 volts
secondary: 50,000 volts

Essential substance of paper 49-60, "Radio Influence From High-Voltage Corona," recommended by AIEE communications and transmission and distribution committees and approved by the AIEE technical program committee for presentation at the AIEE winter general meeting, New York, N. Y., January 31–February 4, 1949. Scheduled for publication in AIEE *TRANSACTIONS*, volume 68, 1949.

Gordon R. Slemon, formerly with the Hydro-Electric Power Commission of Ontario, Toronto, Ontario, Canada, is now with the department of electrical engineering, University of Toronto.

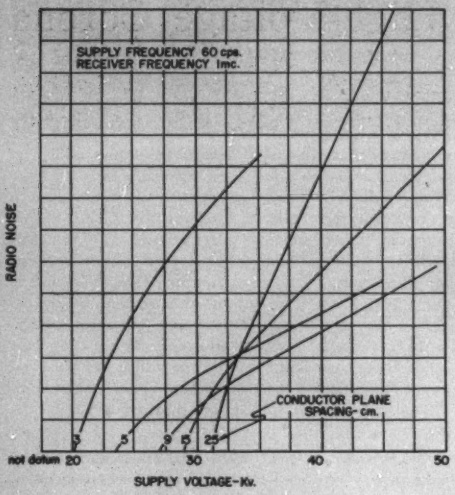


Figure 2. Radio noise versus supply voltage with various conductor-to-plane spacings

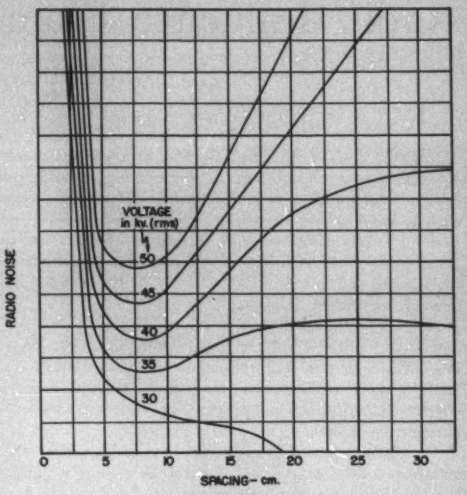


Figure 3. Radio noise versus conductor-to-plane spacing for various applied voltages

A-C CORONA CHARACTERISTICS

The first set of tests were concerned with the corona characteristics of alternating voltage on a smooth, polished conductor.

Corona Threshold Voltage. To cause ionization of atoms by a single electron collision, a certain critical voltage gradient is required throughout the mean free path of the electron. This gradient is a function of the gas ionization potential and the gas density. For air, the gradient required at the surface of a conductor of radius, r, is given in Peek's formula[3]

$$g_c = 29.8\ (K)\left(1+\frac{0.301}{\sqrt{K\times r}}\right) \text{ kv per centimeter}$$

where

$$K = \frac{3.92b}{273+t}$$

b = pressure in millimeters of mercury
t = temperature in degrees centigrade

The voltage which will produce this surface ionizing gradient has been calculated as

$$e_c = g_c r \frac{\left(\frac{s}{r}-1\right)}{\left(\frac{s}{r}+1\right)} \cosh^{-1}\frac{s}{r} \text{ kv peak}$$

where s is the spacing from the conductor center to the plane in centimeters.

The corona threshold voltage was observed experimentally by radio interference, audible noise, and visible light. All three propagations were initiated at the same voltage and this voltage corresponded closely in all cases to the critical corona voltage calculated in the foregoing. The corona threshold was found to be independent of the frequency of the supply voltage over the range studied. The voltage of corona initiation with increasing voltage was found to coincide with that of corona extinction on decreasing voltage.

Radio Noise. Figure 2 shows a typical set of curves of radio noise with supply voltage as the independent variable. It is noted that the curves are very nearly linear with the exception of the low intensity portion which has a greater slope. This would indicate that the magnitude of the radio noise from a smooth conductor is roughly proportional to the increase of the applied voltage over the threshold value.

In Figure 2 it is noted that the minimum slope occurs for the 5–9 centimeter region of spacing. In Figure 3, the same results are replotted on an abscissa of spacing. These curves indicate that, if radio noise is to be allowed, there appears to be an optimum spacing which will produce the lowest value of noise for a particular voltage. Since the amplitude of propagated radio noise is dependent on the complex factors of conduction and absorption of corona energy, there might be doubt as to the applicability of the conductor-plane results to a transmission line. There is some confirmation of possible analogy in this factor, in the work of H. L. Rorden.[4] In his work on a 220-kv transmission line, he found that the radio noise at a short distance perpendicular to the line could be reduced by about half by a reduction in conductor flat spacing from 27 feet to 18 feet.

As to the relative intensities of radio noise over the radio-frequency spectrum, a reduction in noise intensity

with increase in receiver frequency was noted in all cases.

Phase Analysis. The audio output of the radio noise meter and a voltage in phase with the supply voltage were applied to the vertical plates of a double-beam oscilloscope. Figure 4 shows that radio noise is produced in this smooth conductor case only in the region of voltage about the negative peak of the wave. In the range of voltage up to double the threshold value, no radio noise occurred in the positive half-cycle.

The audio output of the meter appears as a series of random pulses of almost equal amplitude phased in a clearly defined group. As the voltage is increased above threshold, the phase width of the group increases; the amplitude of the group, however, remains almost constant. Accurate measurement of the phase limits of the group showed that the radio noise for the lower supply frequencies occurs only during that portion of the negative wave for which the voltage is in excess of the threshold value. Using a 500 cycles per second supply the phase of corona initiation was advanced from 5 to 10 degrees beyond the 60 cycles per second case indicating a possibility of residual ionization effect.

Corona Current. Observation of the corona current wave showed that the positive portion of the wave was smooth. On the negative portion, current pulses were superimposed, as shown by Figure 5. The lower frequency components of the corona current were removed by a short time-constant, differentiating circuit leaving only the high-frequency noise-producing currents shown in Figure 6. These wave forms were compared with those of receiver audio output in Figure 4 and the corresponding phases of initiation and extinction have been found to be identical.

Audible Noise. When the time delay of sound travel from the conductor to the microphone was used as a correction, it was found that the initiation phase for audible sound corresponded closely with that of radio noise. No correlation could be expected on the phase of extinction because of the sound echoes throughout the cage.

Visible Corona. Wave forms of the amplified output of a photoelectric cell focused on the conductor were observed. It was found that the visible corona in the negative voltage cycle was of a pulsating nature and that its phase limits corresponded closely with those of radio noise. The positive-voltage corona produced a relatively constant illumination during the ionized period.

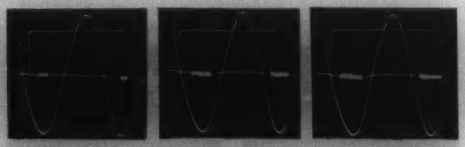


Figure 4. Radio noise from a smooth conductor at 30, 40, and 50 kv

The 60-cycle timing wave is in phase with supply voltage

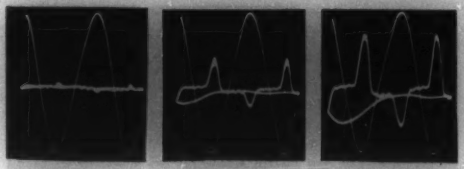


Figure 5. Corona current on a smooth conductor at 30, 40, and 50 kv

The 60-cycle timing wave is in phase with supply voltage

RECTIFIED SINE WAVE-FORM CHARACTERISTICS

In some of the theories which have been advanced on the subject of conductor corona, the effects of residual ionization from the positive voltage cycle have been considered important in the transient phenomena noted during the negative half-cycle.[1] To analyze this interrelation, it was thought desirable to apply the positive and negative half sine waves of voltage to the conductor separately. To do this, a high-vacuum rectifier was placed in series with the high-voltage lead to the conductor.

With the positive sine wave, no radio propagation was observed up to the maximum voltage of 62.5-kv peak. The normal threshold voltage was 38.2-kv peak. The thresholds of audible and visible corona coincided with the alternating-voltage value. The nature of the audible noise was a low-amplitude modulated hiss rather than the staccato pulse observed on alternating current. A bluish-white glow appeared about the conductor while in corona. The intensity was found to be roughly proportional to the excess of the applied voltage over threshold value.

Applying the negative sine wave of voltage, no noticeable difference was observed in the results of these tests and those made on alternating current. It would appear then that a theoretical analysis of corona in the negative cycle of an alternating-voltage wave will have to be based on charges produced during that negative cycle.

D-C CORONA CHARACTERISTICS

A study of the corona phenomena with direct current was indicated for several reasons. The effect of rate of change of voltage is eliminated from the list of variables, direct current provides the simplest case for theoretical analysis of the phenomena which produce radio noise. And, with the possible advent of d-c transmission the results assume importance.

With positive direct current applied, no radio noise was radiated by the smooth polished conductor up to double the normal ionization voltage. There was a barely audible corona noise having the nature of a hiss, the frequency of which seemed to be dependent on voltage. A bluish-white glow appeared and was found to be unmodulated.

As would be expected radio noise was produced with negative voltage on a smooth conductor. However, the threshold of radio noise occurred at a voltage considerably higher than would be expected from the a-c tests. A

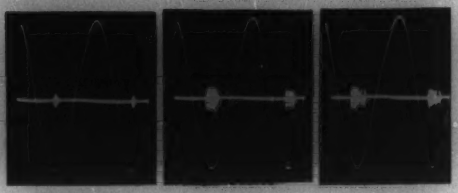


Figure 6. Radio-frequency components of the corona current shown in Figure 5

typical pattern of negative d-c radio noise is shown in Figure 7. The wave form appears to be a mixture of pulses of random amplitudes and of repetition frequencies which increase with voltage increase. Actually, the interference to communications is not nearly so severe with the d-c radio noise because the continuous wave form has no lower harmonics of the power frequency present in a-c noise. The audio output of the receiver is a hiss which can be largely eliminated by limiting the high-frequency audio response of the receiver.

The audible noise from negative direct current shows characteristics which are almost identical with the receiver audio output. The visible corona appears as regularly spaced tufts along the conductor. These tufts are reddish in color and increase in number as the voltage is increased.

EFFECT OF CONTAMINATIONS

Up to this point in the study, all results have applied to smooth polished conductors. To obtain a picture of what might be expected in service, contaminations were introduced.

Mutilations. First, a single burr was produced on the conductor. This burr did not reduce the radio noise threshold, but, as seen in Figure 8, the negative-cycle radio noise remained unchanged and considerable radio noise was introduced into the positive voltage cycle. Since this noise was caused by only one burr, positive-cycle radio noise promises to be severe on mutilated conductors.

Oil and Grease. New conductors on leaving the factory often are coated with a film of die grease. This condition was produced on the test conductor, but no detectible change in radio-noise characteristics from those of a smooth conductor could be observed. Such was not the case, however, when irregular coatings of heavy grease were applied. With positive direct current and in the positive of the a-c cycle, corona brushes appeared, not from the projections but from the thinly greased areas and radio noises occurred in the form of severe pulses.

Weathered Conductors. Prolonged corona on the conductor produced a surface condition similar to that of a slightly weathered conductor. Tests with this surface showed radio noise with negative direct current to be reduced by about 50 per cent in amplitude. When alternating current was applied, radio noise was produced more or less of equal magnitude in the positive and negative half-cycles with a reduction of about 25 per cent in noise meter reading. There is a possibility that tests on a conductor which had been fully weathered in service would show a predominance of positive-cycle radio noise. The radio noise from newly-constructed transmission lines has been observed to reduce after the line has been in service for some time.[4] Generally, this characteristic has been explained by the fact that die grease and surface contaminations, incident to manufacture and stringing, have been burned away by corona. The test observations indicate that this reduction may be partially effected by the added contaminations coincident with conductor weathering.

Water. The severest case of corona occurs under weather conditions of rain, fog, sleet, and snow. Probably the most common and most important conductor surface contamination is, therefore, water. A fine mist of distilled water was produced about the conductor. With positive direct current, severe radio noise was initiated at about 60 per cent of the normal corona threshold voltage. When the mist cleared leaving only the water droplets on the conductor, the radio-noise threshold voltage was increased slightly. It was found that, with negative direct current, water sprayed on the smooth conductor eliminated all radio noise. The radio noise did not recur until the water film was allowed to evaporate from the conductor surface. These results are substantiated by tests on transmission lines using alternating and direct voltages up to 300 kv. It was found that, for otherwise similar conditions the ratio of positive d-c to negative d-c radio noise varied from 3 for fair weather conditions to about 100 for a heavy rain condition.[5]

CONDUCTOR COATINGS

The effects of various conductor contaminations on radio-frequency propagations have suggested the possibility of radio-noise control by special conductor coatings. No attempt has been made here to develop practical coatings but certain of the physical requirements will be indicated.

Positive Direct Current. Of the coatings tested the only one which showed any advantage over the smooth condition was a conducting rubber. When water was sprayed on this coating, the radio-noise threshold was raised about 90 per cent above that of a smooth wet conductor. The amplitude of the signal was comparatively low over the range above the threshold voltage. When dry, the radio noise increased until it was slightly below the value for the smooth, wet condition.

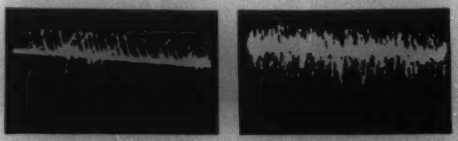


Figure 7. Radio noise from a smooth conductor with 50- and 60-kv negative direct voltage applied

Figure 8. Radio noise with a single burr on a smooth conductor at 40 and 50-kv, showing increased noise during the positive cycle

Negative Direct Current. A carefully applied coat of varnish or enamel gave characteristics similar to those of water on the surface, so that the radio noise was reduced. Irregularities, however, produced severe radio noise. When a conducting coating of sodium chloride was applied as a saturated solution in water and allowed to crystallize, the radio noise was reduced by over 90 per cent from its smooth value. To determine the effect of water on this type of coating, a crystalline surface of dichloro-diphanyl-trichloroethane (D.D.T.) was obtained. The reduction in radio noise was about 75 per cent from the smooth, dry condition. Water was sprayed on the conductor and the radio noise was reduced further to about 70 per cent of the dry coated value.

It was not certain whether the radio noise was reduced by the point structure of the coating or by its value of conductivity. Thus, a smooth coating of conducting rubber was tested with negative direct current. The radio noise was reduced by about the same percentage as for the D.D.T. coating, but, since the audible noise was almost eliminated, the possibility arose that only a few points were producing severe radio noise. These points were isolated by detection of visible corona but the surface could not be repaired easily. It is possible that a well-applied pure coating of conducting rubber might have the same effect as a water film in noise reduction. Water sprayed on the imperfect rubber coating further reduced the noise to about 60 per cent of its dry coated value.

CONCLUSIONS

1. There is an optimum conductor to plane spacing which will produce the lowest value of radio noise from corona on a conductor operating at a voltage above the corona threshold voltage.

2. An increase in the frequency of the supply voltage causes an increase in the magnitude of the radio noise except at conductor spacings lower than the optimum value. The radio-noise threshold is independent of supply frequency.

3. Radio noise from corona on a smooth conductor is produced only during the negative peak of the applied voltage wave. The radio noise occurs within the time during which the negative voltage exceeds the corona threshold voltage for the lower power frequencies. An advance in the phase of radio-noise initiation was observed for supply frequencies of about 500 cycles per second. The effect of residual positive ionization from the positive half-cycle is shown to be a minor factor in the radio-noise phenomena of the negative voltage cycle.

4. The phase of initiation of audible sound and visible light radiations coincides with that of radio noise.

5. Positive direct current on a smooth conductor produces no radio noise with voltages up to double the normal peak threshold voltage.

6. With negative direct current the most severe radio noise occurs with a perfectly smooth conductor. Weathering and most contaminations reduce the radio noise considerably.

7. Water on the conductor causes severe radio noise with positive direct voltage but eliminates radio noise with negative direct current.

8. Radio noise from corona on conductors with negative potential may be controlled by two methods. A smooth coating of high work function will eliminate radio noise by preventing electron emission. A rough, pointed surface of low work function will facilitate electron emission and reduce the severity of the corona current pulses.

9. Radio noise on conductors which are periodically wet may be partially controlled in the positive direct-current case by the application of a semiconducting coating which has a damping effect on the corona current surges.

10. A modification of this semiconducting coating appears to be the best compromise for control of radio noise with alternating current.

REFERENCES

1. Some Characteristics of A-C Conductor Corona, **F. O. McMillan.** AIEE *TRANSACTIONS*, volume 54, 1935, page 282.

2. Factors Affecting the Accuracy of Radio-Noise Meters, **H. E. Dinger, H. G. Paine.** *Proceedings*, Institute of Radio Engineers (New York, N. Y.), volume 35, 1947, page 75.

3. The Law of Corona I, **F. W. Peek Jr.** AIEE *TRANSACTIONS*, volume 30, 1911, page 1889.

4. Expedient Power Line Construction, **H. L. Rorden.** AIEE *TRANSACTIONS*, volume 66, 1947, page 884.

5. Observations of Corona Losses and Radio Disturbances from High-Tension D-C Lines with Heavy Conductors, **B. O. Henning.** Conference Internationale des Grands Réseaux Electriques à Haute Tension, Paris, France, June 27, 1946.

Electronic Reading Aid

A laboratory model of an electronic device which converts reading matter into the sounds of individual letters, thereby enabling a blind person to read printed words, has been demonstrated by the RCA Laboratories, Princeton, N. J., where the device was developed. However, these instruments must undergo further extensive tests and development before they will be ready for general use by the blind.

The latest system, designed for institutions rather than for home use, is large and costly, consisting of a scanning unit, a selector, and a loud-speaker. As the user moves the scanning device along a line of type, a miniature cathode-ray tube explores each letter with eight spots of light arranged in a vertical line. When the spot of light passes over any black portion of a letter, an impulse is sent to the selector unit. There impulses are counted electronically and after the letter has been completely scanned, the total number of impulses is noted by the selector unit. This number, unique for each letter, actuates a magnetic tape recording of that letter and the audible sound is reproduced through the loud-speaker.

The magnetic tapes are wound around the outside of small disks which rotate between special pickup heads. By means of electronic selectors and relays, the disk carrying the recorded sound of the scanned letter or word is put in motion for one revolution and the resulting electric impulses are fed to the loud-speaker. In the experimental model, operation is limited to the 26 letters of the alphabet and a few commonly used words, but the capacity of the system could be expanded indefinitely, limited only by cost and size of the equipment. In addition to its use as a reading aid, the letter recognition instrument has possibilities as a recognition device for the translation of coded patterns such as those which form the basis of teletype messages.

Measuring Conductor Resistance and Reactance

E. H. SALTER
MEMBER AIEE

IN CONNECTION with a study of a-c resistance and reactance of large conductors in steel pipe and conduit, made for the Insulated Power Cable Engineers Association, measurements were made of isolated conductors in air, 3-cabled conductors in air, and finally the 3-cabled conductors in various sizes of conduit. Each of these stages raised measurements problems, especially when it became desirable to determine the component losses due to each of the several factors operating. It likewise became necessary to establish the accuracy with which measurements could be made.

The measurement circuit was essentially that used and described in a previous article.[1] Application of this circuit to the present measurements involved questions as to the proper disposition of potential connections to the conductors. In the case of 3-phase measurements it was found that the apparent resistances of individual conductors in a circuit showed differences of the order of 2:1. Investigation showed, however, that the average resistance of the group was a true measure of conductor resistance and that individual variations in this case were due to mechanical dissymmetries in arranging the conductors for test. Measurements by several different methods demonstrated that the probable accuracy was at least as good as ±0.25 per cent in the determination of a-c resistance.

In connection with the single-phase measurements of isolated conductors, it became desirable to determine the change in resistance due to proximity of other conductors carrying currents. When measurements were attempted it was found that the potential circuit arrangement had to be modified between the condition for an isolated conductor and that for measurement with another conductor nearby. The curve showing variation in a-c–d-c resistance ratio as a function of spacing between conductors then turns out to be the composite curve shown as Figure 1 in which the dotted curve is the probable true curve.

While at work on this problem it was found that in spite of the fact that measurements were being made in a steel-framed building, measured resistances did not indicate added losses due to proximity of this structure as long as the loop made by the potential circuit was kept in close to the conductor under study, but did show these losses as soon as the potential circuit loop was enlarged. This suggests that in such measurements the a-c losses measured are determined by the flux linking the potential circuit only rather than by the total flux linking the current loop. Current magnitude was found to have a negligible effect on the effective resistance of a given conductor arrangement in air or in conduit, though the heating due to that current might so change the conductor temperature as to have a marked effect.

A measure of the losses occurring in the body of the conduit as distinguished from those resident in the conductors was made through comparative studies of transient temperatures immediately following energizing the circuit. These studies included operation with the conductors carrying a normal a-c load, the conductors carrying a d-c load to produce the same total loss and with d-c heating of the conduit itself.

Digest of paper 48-249, "Problems in the Measurement of A-C Resistance and Reactance of Large Conductors," recommended by the AIEE insulated conductor committee and approved by the AIEE technical program committee for presentation at the AIEE Midwest general meeting, Milwaukee, Wis., October 18–22, 1948. Scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

E. H. Salter is a research engineer with the Electrical Testing Laboratories, Inc., New York, N. Y.

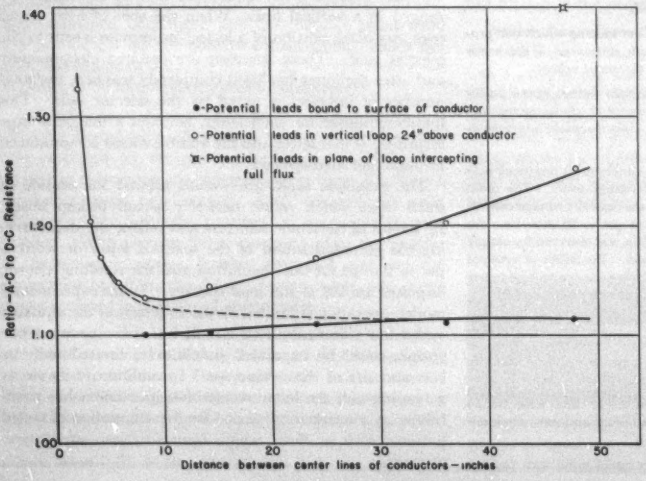


Figure 1. Effect of potential circuit arrangement on the measured a-c resistance in air, single-phase, at various conductor spacings

REFERENCE

1. Resistance and Reactance of 3-Conductor Cables, E. H. Salter, G. B. Shanklin, R. J. Wiseman. AIEE *TRANSACTIONS*, volume 53, 1934, December section, pages 1581–9.

Electrical Essay

Electromagnetic Space-Ship

THE USUAL TYPE of powered vehicle requires a material medium upon which the vehicle exerts its thrust or traction. Thus the locomotive pushes back on its track; the propeller-driven airplane pushes back upon the surrounding atmosphere; even the jet-airplane or rocket pushes back on the discharged gases. In this essay is described a means of propulsion which does not require any material medium upon which the propelling thrust is exerted. It will be suitable, therefore, for driving space ships in interplanetary or interstellar journies and I earnestly call it to the attention of promoters and investors who contemplate entering into this virgin field of activity.

The principles upon which the invention of this essay is based, are elementary, widely known, utilized, and proved in every dynamo-electric machine, and universally accepted. Nevertheless, let us review these elementary principles.

1. Force on a Current in a Magnetic Field. A current of i amperes, flowing along a length of l centimeters, and in a perpendicular magnetic field of H gauss, will experience a force or thrust F dynes which will be perpendicular to the current and the magnetic field, and which is given numerically by

$$F=\frac{Hil}{10}$$

The correctness of this formula is verified millions of times daily on the test floors of the plant at which the writer works. In Figure 1, a conductor AB carries current in a magnetic field set up by a permanent magnet with poles N and S. The thrust at right angles is shown by the arrow F. If the conductor AB is not held fast, the conductor AB will be moved by the thrust. In the electric motors manufactured by my company, the conductor AB does move.

2. Reaction of Current on Magnet or Magnetic Field Structure. Corresponding to the thrust F on the current AB of Figure 1, there is an equal and opposite thrust on the poles of the magnet, N, S. This comes about because the current AB produces a magnetic field which links it by a right-hand rule as shown in Figure 2. This magnetic field above the current AB acts on the magnetic pole N with a push shown as $F/2$. The magnetic field below the current is in the opposite direction, but the pole S is also of opposite polarity, so that the push on the pole S is in the same direction as that on N. The total push on N and S is just equal and opposite to the push on the current AB, illustrating a principle attributed to Isaac Newton.

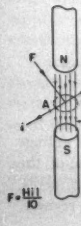


Figure 1

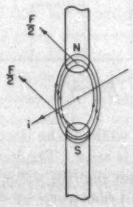


Figure 2

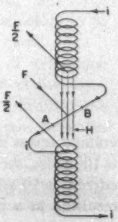


Figure 3

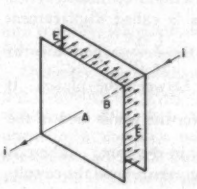


Figure 4

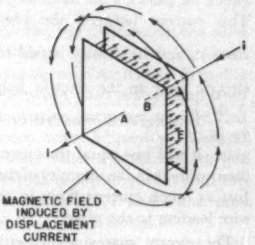


Figure 5

The poles of the stators of the motors which my company manufactures are fastened down very securely so that they will not be moved by this force of reaction of the current on the magnetic field structure.

3. An Electromagnet May Replace the Permanent Magnet. It is well known that a solenoidal coil of wire carrying current produces a magnetic field entirely similar to that of a permanent magnet. This similarity even extends to its also producing a thrust F, on the current AB as is shown in Figure 3. Likewise the current AB through its magnetic field exerts a reaction force on the solenoid coils which is equal and opposite to F.

For convenience and economy we may use the current going through AB for also exciting the electromagnets.

In the machines manufactured by my company, electromagnets very successfully replace permanent magnets.

4. Alternating Current May Replace Direct Current. If in Figure 3, we use alternating current instead of direct current, the magnetic field acting on AB also will be alternating. However, just at the moment the magnetic field reverses, the current AB also reverses. Hence the thrust F will not reverse but always will be in the same direction. Hence even with alternating current the current AB will continue to be pushed in the same direction as in Figure 3. Also, the alternating current field structure will be pushed in the opposite direction, as shown in Figure 3.

The a-c series commutator motors which my company manufactures really do run very well.

5. There Are Displacement Currents. If a high enough frequency is used, then a break in a circuit has very little effect upon the flow of current in the circuit. In Figure

4, the section of the conductor *AB* has been removed, and replaced by empty space between two large parallel plates. If these plates are a yard square, and a foot apart, then only a few thousand volts will send a thousand amperes of current through the circuit, including the empty space between the plates, if the frequency is a hundred million cycles. This current between the plates is called displacement current, and its density is said to be $\frac{1}{4\pi}\frac{\partial E}{\partial t}$, where E is the electric force in the electric field between the plates. If $\frac{1}{4\pi}\frac{\partial E}{\partial t}$ is integrated or added up over the whole area of the plate, it will just equal the current in the wire. There is then no break in the intensity of the current round the circuit. Just as much current flows in the empty space, as in the wire leading to the plate.

The empty spaces made with vacuum pumps in the research laboratory of the company by which I am employed are very efficient in carrying displacement currents. They heat up hardly at all, even with quite intense displacement currents.

6. Displacement Currents Are as Good as Any Other. Clerk Maxwell states that displacement currents produce magnetic fields in exactly the same way and in precisely the same degree as any other currents. In fact that is why electromagnetic waves propagate and give us radio. Hence, as shown in Figure 5, there will be a magnetic field circling the displacement currents. At a radius beyond the plates, the magnetic field produced by the displacement currents is just as large as that produced if the conductor *AB* replaced the empty space, and carried the same current.

7. Driving Force for a Space Ship. Now, to get a driving force for a space ship, all we need to do is to put the magnet system of Figure 3, together with the displacement currents of Figures 4 and 5. Then we get the system shown in Figure 6. Fasten this securely to the body of a space ship, connect the terminals to a source of 100 million cycle power, and off she will go. If we put 1,000 amperes in the space between the plates (which is easy), and 5,000 gauss in the coils, (my company puts more than 10,000 gauss in its field poles) then the force will be

$$\frac{Hil}{10} = \frac{5000 \times 1000 \times 30}{10}$$

or 15 million dynes. That is a lot of force, but if it is not enough, we can make the empty space larger, or we could have a battery of these electromagnetic propulsion machines working together. In this last case we could steer by reversing some of the machines. If we reverse all the machines we have regenerative braking!

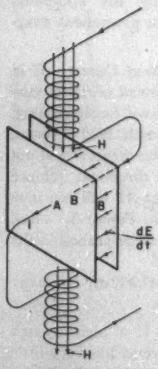


Figure 6

The reader may be puzzled by the force of 15 million dynes on the empty space between the plates in Figure 6 because this space is immaterial. However, this question itself is immaterial to the success of my invention, the space ship. The driving of the ship depends upon the real force coming from the action of the magnetic field of the current i upon the field poles. These poles are just as material as the poles on my company's motors, and a magnetic field will act on them with just as material a force.

By describing this invention in an electrical essay, instead of a regularly submitted technical paper, I avoided the annoying questions and criticisms of reviewers. However, now I am committed to leaving the readers with some questions to answer. Therefore:

1. In principle, is there an unbalanced or net force on the material system of the space ship of the same nature and with magnitude of the same order as that described and estimated in the essay?

2. In principle, can this unbalanced or net force drive the space-ship on its journey?

Author's answers: Question 1. Yes. Question 2. No.

J. SLEPIAN (F '27)
(Associate director, Westinghouse Research Laboratories, East Pittsburgh, Pa.)

Answer to Previous Essay—The Black Box

The following is the author's solution to the previously published essay entitled, "The Black Box" (*EE, Jan '49, p 29*).

The black box contains nothing but a mechanically driven switch, (perhaps by a spring motor). The circuit is closed half of the time, and open half of the time, but the interruptions are of a high enough frequency, to make the meters read the steady average value. The current therefore consists of 20-ampere pulses, followed by periods of zero current of equal length. The wattage in the black box is zero because at the time when the current flows, the voltage across it is zero, while at the time when the voltage is 100 volts, the current is zero. The average value of the current is 10 amperes, but the rms value is 14.12 amperes, resulting in a power of 1,000 watts in the 5-ohm resistor.

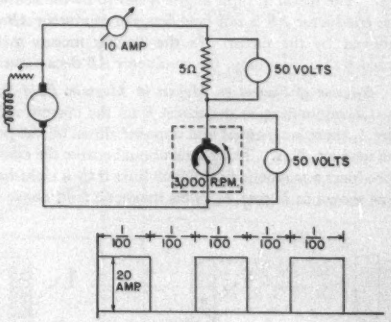


Figure 1

WALTHER RICHTER (F '42)
(Allis-Chalmers Manufacturing Company, Milwaukee, Wis.)

Coaxial Telephone-Television System Progress

L. G. ABRAHAM
MEMBER AIEE

DEVELOPMENT OF the coaxial system was started some time ago, with systems working before the war between New York, N. Y., and Philadelphia, Pa., and between Minneapolis, Minn., and Stevens Point, Wis. There are about 5,000 route miles in service providing almost three million miles of 2-way telephone circuits plus television network facilities. The entire program for the next few years roughly will triple the route miles and more than triple the circuit miles. Miami, Fla., now can talk over coaxial systems across the continent to Los Angeles, Calif., a distance of about 3,000 miles. It is also possible to talk from Albany, N. Y., to Charlotte, N. C., or from Buffalo, N. Y., to St. Louis, Mo., and by the middle of 1949, it will be possible to talk from New York to Los Angeles via Chicago over coaxials.

There is a television network working from Boston, Mass., to Richmond, Va., a distance of about 600 miles, with radio relay from Boston to New York and coaxial for the remaining distance. There are dropping points at Philadelphia, Baltimore, and Washington in addition to the terminals. There is a Midwestern television network for service this fall to connect St. Louis, Chicago, Toledo, Cleveland, and Buffalo by coaxials, with Milwaukee, Detroit, and other points along the route connected in by radio relay. It is expected that by early in 1949, these two networks will be connected together by coaxial cable from Philadelphia to Cleveland via Pittsburgh, with a maximum television circuit distance of about 1,500 miles.

The *L1* coaxial system is capable of transmitting, on two coaxials and their associated equipments, 600 telephone circuits or alternatively a 2-way television circuit 2.8 megacycles wide. This system has presented a number of difficult technical problems. The step from the older cable carrier systems having 12 channels to a system with 600 channels was a large one and television transmission introduced additional requirements over telephone transmission. Such a coaxial system is designed to give satisfactory telephone and television circuits for up to 4,000 miles. The total cable loss for a 4,000-mile circuit is about 27,000 decibels at the top of the transmitted band and about 4,000 decibels at the bottom, thus requiring large amounts of gain and gain equalization. But large numbers of systems now are working and the solutions to remaining problems seem foreseeable or in hand.

Carrier methods of obtaining groups of telephone circuits have made much more effective use of line conductors than voice-frequency systems. In addition, the need for special services such as sound program networks and recently, television networks, has emphasized the need for wide frequency band facilities.

Ordinary paper-insulated cable pairs are limited in usable top frequency by crosstalk between pairs and pickup from the ether. Also, their attenuation increases rapidly and often in a complex manner with frequency. Coaxial conductors with relatively solid outer conductors are not limited by crosstalk or pickup as to top frequency and the attenuation can be kept reasonably low and quite predictable at high frequencies by suitable design.

The use of wide frequency bands over coaxial conductors has required close repeater spacing. For economy, most repeater stations must be kept simple and efficient maintenance means made available. The maintenance and repair of used apparatus must be provided for at suitable points. Power for normal operation must be supplied so that frequent and expensive power plants are avoided. Avoidance of system failure is very important when such wide bands are used over one system. These factors lead to most repeater stations being unattended, maintenance by men who visit these stations periodically with portable test apparatus, power fed over the coaxial centers from widely spaced points, and alarm and control systems to insure reliability and warn of potential trouble.

Due to the large numbers of repeaters in tandem with the longer circuits, very precise gain and phase equalization per repeater is required. This requires close control of manufacture and maintenance, and means for mopping up residual deviations at suitable intervals, partly on a manual basis and partly automatically. Since temperature changes, aging of apparatus, and power changes cause considerable loss and gain changes in relatively short times, dynamic regulators operating from pilot frequencies transmitted over the system are used to make automatic gain characteristic adjustments. The tandem operation of large numbers of dynamic regulators has required considerable engineering advances to avoid instability due to the accumulated effects of many small changes in the pilots, particularly as magnified in passing through the circuit. Control of noise and modulation and definite location of amplifiers which have become defective from these standpoints are necessary.

It seems pretty clear that telephone service over our longest coaxial systems will be satisfactory from a modulation and noise standpoint since 3,000-mile systems equipped with a considerable number of circuits already are giving satisfactory service. On television circuits, there are not enough data as yet to be sure. Certain improvements which can be made in the television terminals to give improvements in modulation products for a given signal-to-noise ratio make it seem likely that commercial television pictures can be transmitted across the entire country by coaxial systems.

Digest of paper **48-273**, "Progress in Coaxial Telephone and Television Systems," recommended by the AIEE communication committee and approved by the AIEE technical program committee for presentation at the AIEE Midwest general meeting, Milwaukee, Wis., October 18–22, 1948. Scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

L. G. Abraham is with the Bell Telephone Laboratories, Inc., New York, N. Y.

Rural Inductive Co-ordination Practices

M. W. ROTHPLETZ
MEMBER AIEE

H. S. WILLIAMS
MEMBER AIEE

Many electrical interference problems have arisen with the construction of power lines in the vicinity of communication lines throughout rural America. This article covers the solution of many of the numerous inductive co-ordination problems involving rural power and communication circuits.

WITH THE extension of central station electrical service into rural areas the problems of preventing interference to communication circuits have multiplied. Many of the conditions that tend to cause interference are accentuated considerably in rural power and communication systems as compared to urban systems. However, by properly co-ordinating power and communication lines on an inductive basis it has been possible to operate both types of service in close proximity. Recent developments in the inductive co-ordination art have been accepted and utilized as a matter of course with little attendant publicity. Many of the advances described here apply equally well to urban and rural power systems; however, this article is concerned primarily with inductive co-ordination of rural power and communication circuits.

Inasmuch as inductive co-ordination is a specialized field, it may be well to define some of the terms which will be used in the discussion. Three main factors must be considered in any situation when inductive co-ordination is necessary.

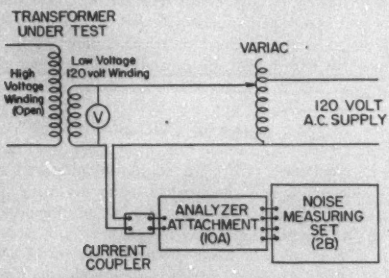


Figure 1. Connections for measurement of harmonic exciting current of distribution transformers

1. Inductive influence—those characteristics of an electric supply circuit with its associated apparatus that determine the character and intensity of the inductive field which it produces.

2. Inductive susceptiveness—those characteristics of a signal circuit with its associated apparatus which determine, so far as such characteristics can determine, the extent to which it is capable of being adversely affected by a given inductive field.

3. Inductive coupling between two circuits—the interrelation of neighboring electric supply and signal circuits by electric or magnetic induction or both.

For our purposes we need two additional terms:

1. *TIF*—The telephone influence factor of a voltage or current wave is the ratio of the square root of the sum of the squares of the weighted rms values of all the sine wave components (including both fundamental and harmonic) to the rms value (unweighted) of the entire wave.

2. *I×T*—The *I×T* product of a current wave is the product of the magnitude of the current wave in amperes (rms values unweighted) times its *TIF*.

When power lines began to extend across rural America, telephone lines already served some of these areas to a greater or lesser degree. Some of these telephone lines had been in operation since the turn of the century and in many cases were operating satisfactorily with a minimum of maintenance. Many of these lines consisted of only one circuit and were of the one-wire ground-return type. In the absence of power lines, this type of system served adequately, although crosstalk became a serious problem when more than one telephone circuit was built on the same pole line. With the energization of a power line in the vicinity of one of these ground-return telephone circuits the telephone became practically unusable.

Various means of correcting this situation were investigated. An amplifier-attenuator was tried on the telephone circuit. This device amplified the voice signal at the beginning of the exposure and attenuated it at the other end. With this arrangement the voice signal level was high through the parallel where interference was picked up. When the voice and the interference signals were attenuated back to the normal voice signal level, the interference was reduced greatly. The most serious limitation of this system was the crosstalk resulting from the high signal level. Consequently the equipment was not further developed. It became apparent rather early that the only practicable means of continuing telephone service to rural people who also were becoming power users was to metallicize the telephone circuits.

Merely metallicizing the telephone circuit by adding a second conductor is not sufficient. To be fully effective, the two conductors must be transposed properly, have low resistance joints, and be well insulated from ground. Any telephone apparatus connected to ground increases the susceptiveness of the telephone circuit. However, if these impedances to ground are relatively high and balanced

Essential substance of paper 48-242, "A Survey of Inductive Co-ordination Practice in Rural Areas," recommended by the AIEE communication and transmission and distribution committees and approved by the AIEE technical program committee for presentation at the AIEE Middle Eastern District meeting, Washington, D. C., October 5–7, 1948. Not scheduled for publication in AIEE *TRANSACTIONS*.

M. W. Rothpletz and H. S. Williams are both with the Rural Electrification Administration, Washington, D. C.

between the sides of the circuit and ground, the susceptiveness usually will be satisfactory.

Noisy circuits caused by induction from power lines cannot be cleared up by the telephone people without the cooperation of the power suppliers. In general, power equipment containing iron in its magnetic circuit generates voltages whose frequencies are multiples or harmonics of the fundamental frequency. The magnitude and frequency of these harmonic voltages depend on the type of magnetic material and the portion of the magnetization curve on which the equipment is operating.

In urban areas where exposures between power and telephone circuits are relatively short and the shielding benefits afforded by telephone cable sheaths and other grounded metallic structures is usually large, the magnitude of these harmonics has not been as important as on rural circuits. On rural circuits it soon was apparent that a relatively low level of harmonic voltages and currents had to be maintained. In numerous instances at the outset of the rural program, inductive co-ordination problems resulted when lightly loaded distribution circuits obtained power from sources having reasonably good wave shapes.

It was found upon investigating several of these problems that a large number of distribution transformers operating at high flux density generated enough harmonic currents in the range of 180 to 900 cycles to render comparatively well balanced telephone circuits inoperable. These large harmonic currents generally resulted when transformers designed to operate at flux densities near the saturation point, were operated at voltages somewhat in excess of their ratings. It was found that with transformers designed to have an exciting current $I \times T$ product of 15, or less, per kilovolt-ampere on the 120-volt base, problems of this sort practically could be eliminated. The voltage applied to the transformers, of course, must not exceed the rated voltage appreciably. Table I presents a comparison of the harmonic analysis of two 3-kva 7,200/120-volt transformers, one with an acceptable $I \times T$ product and the other not acceptable.

Table I. Harmonic Analysis of Two 2-Kva 7,200/120-Volt Transformers

Frequency	Transformer Number 1 (Acceptable)	Transformer Number 2 (Not Acceptable)
Over-all $I \times T$ product	36	380
180-cycle contribution	6	18
300-cycle contribution	21	109
420-cycle contribution	8.3	155
540-cycle contribution	3.6	125
660-cycle contribution	12	79
780-cycle contribution	11	94

These measurements were made by use of a noise measuring set connected to the transformer under test as shown in Figure 1.

On some rural power systems served by small generating plants the harmonic voltages in the power sources caused serious noise problems. To alleviate problems of this type, it was necessary to design resonant shunts which would effectively short-circuit the harmonic voltages at the generator bus. The shunts were constructed with standard power factor correction capacitors and air-core inductances tuned to series resonance at the offending frequency. Where more than one harmonic voltage was predominant in the power source wave shape, a broadly tuned shunt sometimes was used if the frequencies were adjacent, otherwise two or more shunts were required.

As a result of early investigations, it was decided that to avoid a deluge of noise problems caused by poor generator wave shape, it would be necessary to control the harmonic voltages produced by generators. It was found that noise problems attributable to distorted generator wave shape probably would not be created if the generators were designed with open circuit *TIF* values no higher than 15. This *TIF* limit subsequently was included in the generator specifications of the Rural Electrification Administration.

Generator manufacturers have altered their designs and now are supplying generators that meet this *TIF* limit. One manufacturer reported the results of experimental

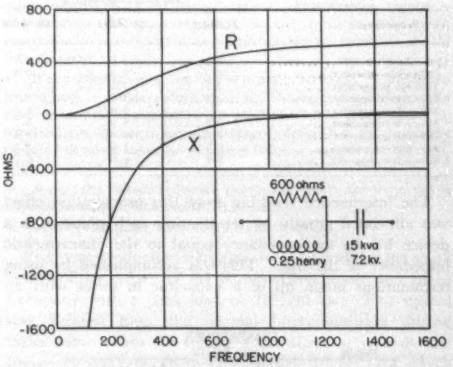


Figure 2. Impedance characteristic of a termination for use on 7.2/12.5-kv rural line

changes made on one of his machines. These changes consisted of skewing the stator slots, changing the rotor pole face contour, and partially closing the slots. The results of these experiments are shown in Table II.

Table II. Effect of Experimental Changes in Generator Designs

Test Condition	Voltage TIF No-Load
1. Original design—open slots	35.4
2. Stator slots skewed one slot-pitch, open slots	17.4
3. Stator slots skewed one slot-pitch, open slots, rotor pole face contour changed to have gap at tip double the gap at center but the same average air gap as original machine	30.2
4. Same pole face contour as in number 3 above, stator slots skewed 1.04 slot-pitch and slots partially closed	10.4
5. Stator slots skewed 1.04 slot-pitch, slots partially closed, poles of regular contour and uniform air gap	12.1

Name plate data—62.5 kva, 0.8 power factor, 60 cycle, 1,200 rpm, 480 volts, Y-connected.

It is apparent that skewing the stator slots had the greatest effect in improving the generator wave shape. Partially

closing the slots also contributed considerably towards improving the machine characteristics.

As rural power lines were lengthened a new problem arose. Some of these lines were extended, by adding successive sections, until they approached one-quarter wave length at frequencies in the audible range and a resonant condition resulted. Thus, with a power source of reasonably good wave shape, harmonic voltage rise along the lines became evident. In some instances this resulted in serious noise problems because of increased ground return harmonic currents. Results of actual measurements of harmonic voltages along a 7.2/12.5-kv power line are shown in Table III. The rise in the 780-cycle component is particularly noticeable.

Table III. Harmonic Voltages Measured Along a 7.2/12.5-Kv Power Line

Frequency	Distance From Source		
	24 Miles	34 Miles	38 Miles
Over-all voltage *TIF*	12.1	15.0	21.1
180-cycle component	0.3	0.3	0.3
300-cycle component	6.3	7.1	6.3
420-cycle component	2.9	3.9	3.9
540-cycle component	1.4	1.4	1.0
660-cycle component	2.8	3.6	3.2
780-cycle component	7.6	10.8	17.4
900-cycle component	0.9	1.6	2.6
1,020-cycle component	3.8	6.1	6.5

The interference resulting from this propagation effect was alleviated greatly by terminating each phase with a device having an impedance equal to the characteristic impedance of the line. This was accomplished by using terminations made up of a capacitor in series with an

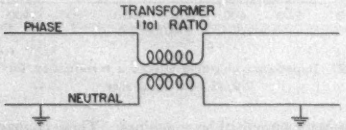


Figure 3. Schematic diagram showing the "sucker transformer" connection used to equalize the flow of current in phase and neutral conductors

inductance shunted by a resistor. This device was developed by H. W. Wahlquist, Ebasco Services, Inc., formerly engineer of Edison Electric Institute, and commonly is termed the "Wahlquist termination." The impedance characteristic of one of these terminations is shown in Figure 2. By means of this device on the power line, noise in parallel telephone circuits has been reduced by six decibels or about 50 per cent.

Telephone circuits have not been the only communication lines with which it has been necessary to co-ordinate rural power lines. Telegraph and signal circuits operating at low frequencies also have had to be considered. Because most telegraph circuits are operated with ground return the remedial methods applicable are limited. In most cases the interference results from 60-cycle induction. Because the 60-cycle current cannot be reduced, the best results have been obtained by using cancellation effects. On single-phase lines this effect may be obtained by the so-called "sucker transformer" or by the use of an isolating transformer.

The sucker transformer is in effect a one-to-one ratio current transformer with the primary in the phase conductor and the secondary in the neutral (Figure 3). The result is to force the same current to flow in the neutral as in the phase conductor. Because these two conductors are near each other in relation to the distance to the communication line, the net induction on the communication line is small.

With the isolating transformer connected as shown in Figure 4, a transposition is effected in the power line. The connection is made so that the current flows in opposite directions in the phase conductor on the load and supply

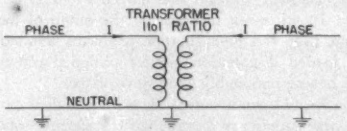


Figure 4. Isolating transformer connected to reverse direction of current flow in phase conductor

sides of the isolating transformer. This arrangement is quite satisfactory when the power line current is uniform throughout the parallel; however, if the separation from the communication circuit is not uniform or if loads are supplied at points within the parallel, it is rather difficult to find the proper location for the transformer. Changes in the power loads may necessitate relocating the transformer from time to time.

We have attempted to cover only some of the outstanding problems met in our inductive co-ordination work. Problems involving multiphase rectifiers, automatic welding machines, and large motors as harmonic generators have been encountered on rural power systems. Where these devices were the causes of inductive co-ordination problems, resonant shunts similar to those used on generators were installed. No doubt new problems will develop in the future requiring the full-co-operation of power, communication, and design engineers to the end that the general public may continue to enjoy both power and telephone service.

REFERENCES

1. Inductive Co-ordination of R.E.A. Distribution Systems and Telephone Systems **K. J. Plucknett, W. T. Smith, T. A. Taylor.** AIEE *TRANSACTIONS*, volume 60, 1941, pages 586–95.

2. Noise Co-ordination of Rural Power and Telephone Systems, **H. W. Wahlquist, T. A. Taylor.** *ELECTRICAL ENGINEERING*, volume 57, November 1938, pages 613–21.

3. Sucker Transformer Reduces Induction, **Theodore Seely.** *Electrical World* (New York, N. Y.), October 30, 1943, pages 80 (1544).

4. A Review of the Operation and Inductive Coordination of Telegraph Systems, **St. Cyr, North.** *Edison Electric Institute Bulletin* (New York, N. Y.), April 1943, pages 107–12.

5. Inductive Coordination of REA Lines and Bell System Lines, **Moore, Huntley.** *Electrical World*(New York, N. Y.), October 13, 1945, pages 96–8.

Emergency Control of System Loads

J. M. COMLY MEMBER AIEE G. B. KELLEY MEMBER AIEE J. E. McCORMACK FELLOW AIEE

H. W. PHILLIPS T. W. SCHROEDER MEMBER AIEE

THE SMALL MARGIN of reserve capacity existing throughout the electrical utility industry due to war and postwar shortages has created an increasing interest in methods of load reduction to meet temporary emergency conditions until normal capacity can be restored. Voltage and frequency reductions within limits will affect customers very minutely. However, the over-all reduction on a large system may be sufficient in most instances to avoid the necessity of interrupting load.

There is substantial agreement by operating companies as to the effectiveness of voltage reduction but there is considerable disagreement as to the effect of frequency reduction and the feasibility of applying frequency reduction to interconnected systems. The purpose of this article is, first, to point out the effect of frequency reduction on the component parts of the load and on the system as a whole; and second, to give the results of tests on a large interconnection and on a small isolated system.

In broad general principles, a reduction in frequency is synonymous with slower operation of rotating equipment, and at slower speeds less work is done. Since the magnitude of the components of system load is generally unknown, it is impossible to predict accurately the effect of frequency reduction on any particular system without adequate tests and study. Most systems operate as part of an interconnection where attempts to reduce frequency may affect load transfers seriously and cause overloading of interconnecting ties. Reductions in frequency entail a reduction in voltage at the generating bus, which accounts for a part of the load reduction unless steps are taken to maintain voltage at normal. Further, electrically driven auxiliaries will slow down and tend to reduce station capacity when maximum generation is desired.

The results of frequency reduction tests made on the Pennsylvania-New Jersey and the Baltimore-Washington Interconnections with a combined system load of approximately five million kilowatts show that a frequency reduction of 1 per cent will give an over-all load reduction of 2.6 per cent. Of this over-all reduction, 1.9 per cent results from the reduction of synchronous and asynchronous loads while 0.7 per cent accrues from the net reduction in resistance load. On the basis of these tests, the Pennsylvania-New Jersey Interconnection has been able to establish a workable plan for voltage and frequency reduction under emergency load conditions, an outline of which is as follows:

1. The normal spinning reserve for this area is 236,000 kw.
2. When the spinning reserve drops below 100,000 kw, the interconnection dispatcher issues a "first voltage warning" to all companies, who in turn communicate it to generating stations and attended substations.
3. When the spinning reserve drops below 50,000 kw, the interconnection dispatcher issues a "second voltage warning." This is communicated to all generating stations. Furthermore, regulators in substations in certain areas are blocked, while in other areas, supervisors go to the substations to supervise voltage reduction, should it be required.
4. If and when the spinning reserve drops to zero, and the frequency is dropping, a voltage reduction up to 7½ per cent is ordered. In those areas where regulators are blocked and in areas where no regulated circuits are in use, the voltage is dropped at the generating station. In other areas the voltage is reduced manually at the regulator.
5. Should the voltage reduction prove inadequate, the frequency is allowed to drop to 59.4 cycles (1 per cent).
6. Beyond this point, load would be interrupted.

Frequency reduction tests also were reported for the small metropolitan system of the Kansas City Power and Light Company with a peak load of 235,000 kw. This system was isolated from the normal interconnection during these tests. With the voltage maintained at normal, the frequency was reduced to 59.5 cycles or 2.5 per cent, which gave a corresponding reduction in load of 4.68 per cent, or approximately 1.87 per cent load relief per 1 per cent frequency reduction. A second test determined the effect of dropping voltage and then applying the frequency reduction with the voltage maintained at that constant value. This confirmed the 1 per cent reduction in load per 1 per cent drop in voltage. In the second part of this test, with voltage 3 per cent below normal, a 1 per cent reduction in frequency effected a 1.78 per cent reduction in load.

It should be possible to lower the system primary voltage as much as 5 per cent, and at the same time decrease the system frequency 1½ cycles. A reduction of approximately 21 megawatts, or 9 per cent, could be expected, provided the regulators in the substations are set on nonautomatic. If sufficient time is available to do so, the regulators in the automatic stations always can be set on the nonautomatic position. However, an emergency might arise where this could not be done, in which case the per cent drop in load due to decrease in the voltage would not equal 1 per cent, but would be possible in the order of 0.3 per cent to 0.6 per cent drop in load for each 1 per cent drop in voltage. Even under this condition, lowering of voltage and frequency is a practical and effective method of relieving the system under emergency conditions.

Digest of paper 48-267, "Emergency Control of System Loads," recommended by the AIEE system engineering committee and approved by the AIEE technical program committee for presentation at the AIEE Midwest general meeting, Milwaukee, Wis., October 18–22, 1948. Scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

J. M. Comly and **J. E. McCormack** are with the Consolidated Edison Company of New York, Inc., New York, N. Y. **G. B. Kelley** and **T. W. Schroeder** are with the United Light and Railway Service Company of Iowa, at Des Moines, and Davenport, Iowa, respectively. **H. W. Phillips** is with the Pennsylvania-New Jersey Interconnection, Philadelphia, Pa.

The Great Lakes Radiotelephone System

R. H. HERRICK

The system is a highly developed voice system of commercial grade "tailored" especially to the unique needs of the Great Lakes shipping industry, and is an important factor in the efficient operation of approximately 600 vessels. The article describes the many services of the system, as well as the ship's and shore station's equipment.

GREAT LAKES shipping is in a class by itself in several respects. Not the least of the characteristic differences between the Great Lakes and ocean shipping industries are the differences in methods of navigation and in dispatching of vessels to obtain the highest possible efficiency of loading and unloading. It, therefore, should be no surprise to learn that the radiotelephone system on the Great Lakes is also unique since it is a large contributing factor to Lakes navigation and dispatching facility.

The Great Lakes radiotelephone system originally was established to serve the shipping industry and therefore was "tailored" especially to the needs of Great Lakes shippers. While its subsequent expansion has included good provisions for pleasure craft and other boats not of a commercial nature, the shipping industry is the major user of the Great Lakes radiotelephone service and the "tailoring" process will continue with the especial objective of serving that great industry to even better advantage. It thus seems desirable to precede a more detailed discussion of the Lakes radiotelephone system by a brief description of the Great Lakes geographical and shipping pictures.

Essential substance of paper **48-316**, "The Great Lakes Radiotelephone System," recommended by the AIEE communications committee and approved by the AIEE technical program committee for presentation at the AIEE Midwest general meeting, Milwaukee, Wis., October 18–22, 1948. Not scheduled for publication in AIEE *TRANSACTIONS*.

R. H. Herrick is with The Lorain County Radio Corporation, Lorain, Ohio.

Great Lakes shipping is the prime iron ore transport medium and is thus the lifeline of the great iron and steel industry. Lakes shipping is also a major grain transport medium, and is an important factor in the delivery of coal and oil to the northern Lakes regions.

Most of the Great Lakes commercial vessels are bulk cargo carriers in which the ore, grain, coal, oil, and so forth is poured directly into the hold of the vessel. The typical Lakes vessel is long (400 to about 650 feet); the unusual length allows cargoes up to 18,000 tons while keeping a comparatively small beam (45 to about 70 feet) and limited draft to allow passage through the locks and narrow rivers and channels characteristic of Lakes navigation.

A major contributor to the notable efficiency of the Great Lakes shipping industry is the highly developed Great Lakes radiotelephone system. It is also a prime safety factor. Lakes navigation is subject to the usual marine hazards plus the narrow channels, fogs, and exceptionally severe storms for which the Lakes are notorious. Occasionally these combine to precipitate emergencies; at such times the reliability, the comparative speed of speech transmission, and the ease of use of the radiotelephone system have saved many lives and a large amount of property.

The radiotelephone is used by practically all of the approximately 400 United States vessels and 200 Canadian

Figure 1. The operating room at shore station WMI, Lorain, Ohio

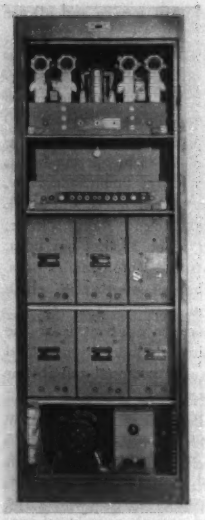


Figure 2. The interior of a ship's typical radiotelephone set showing the radio transmitter chassis on the first shelf, the modulator and control relay chassis on the second shelf, with the six separate radio receivers on the next two shelves, and the power supply at the bottom

ships, about 600 total, operating commercially on the Lakes. Great Lakes communications are almost exclusively by radiotelephone.

The Great Lakes radiotelephone system was started in 1934 by The Lorain County Radio Corporation which established a shore station at Lorain, Ohio, and developed ship radio equipment specifically for Great Lakes use.

The radiotelephone system since has grown to include seven United States shore stations which, with several Canadian shore stations, give a first-class telephone service to Lakes boats of all kinds. The seven United States shore stations are operated by five different companies all of whom are public utilities responsible to the Federal Communications Commission.

Figure 1 is a view of the shore station *WMI* operated by The Lorain County Radio Corporation at Lorain, Ohio, about 30 miles west of Cleveland where many of the Great Lakes shippers have their headquarters. It may be interesting to know that this station and the Duluth station owned by the same company now employ several licensed women operators who handle their share of traffic and are liked generally by the Lakes ship officers. In the Atlantic, Gulf, and Pacific coast systems, traffic generally is handled directly by the regular telephone toll operators located in telephone offices; by contrast, radiotelephone traffic through most of the Great Lakes shore stations is handled directly by the technical operators at the shore stations since this method is best adapted to some of the special services offered by the Lakes shore stations. The Lorain station *WMI* has the status of a "toll center" which means that its operators have direct access to Cleveland subscribers and to the national toll lines.

Typical of the traffic handled on the Lakes, the three shore stations operated by The Lorain County Radio Corporation alone—that is, three stations out of a total of seven United States shore stations—handled more than 108,000 calls during the approximately nine months of the 1947 season.

The total traffic through the seven United States stations probably approximated 200,000 calls and, with the Canadian stations, the gross Great Lakes traffic probably approached 225,000 calls for the approximately 9-month 1947 season.

The Great Lakes radiotelephone system is designated by the Federal Communications Commission as of the "coastal-harbor" type. The original designation "coastal-harbor" was given to the public radiotelephone system serving Atlantic, Gulf, and Pacific coast shipping which is essentially short-range communication as indicated by the name; the Great Lakes radiotelephone system was assigned a similar designation but actually has grown into a combination of short- and long-range communication channels necessitated by the unique requirements of the enormous shipping industry which it serves. Thus the Great Lakes system is in a class by itself, for which no truly applicable official designation has been established.

As already remarked, the Great Lakes radiotelephone system was designed or tailored especially to the needs of the vast and well-integrated Lakes shipping industry. Several different services are provided, all of which are used extensively by Great Lakes shippers; the most important of these services are described as follows.

The system provides for the usual telephone service between ship and shore, including interconnection with the land wire telephone system. Calls may be placed from a ship to any place in the world, or from any place in the world to the ships.

The system also provides a message service in which a message is left with a shore station for delivery to a land point by telephone or printer telegraph at some later time to suit the convenience of the parties concerned. Position reports are an important class of message service, in which

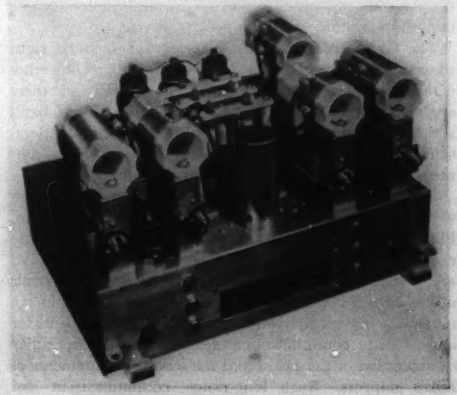


Figure 3. The radio transmitter chassis; it provides six transmitting channels; each with its own tuned circuit

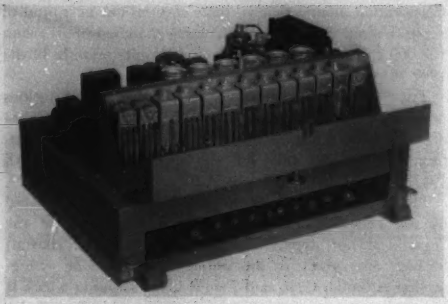


Figure 4. The modulator and control chassis showing the audio amplifier, including modulator, at the rear; basic control relays at the front

the ships' officers periodically report their positions to a shore station; the shore station summarizes these reports and forwards them, at specified times, to the dispatcher at the shipper's headquarters.

Another service of the Great Lakes radiotelephone system is the broadcasting, several times a day, of weather information and predictions furnished by the United States Weather Bureau, and of navigational reports and warnings furnished by the United States Coast Guard and the Hydrographic Office.

An important part of the Lakes radiotelephone system is the ship-to-ship communication channel which allows safety arrangements to be made between ships approaching harbors or a crossing point of traffic lanes, and also makes possible the direct exchange of information to facilitate navigation in general.

And last named, but of first-order importance, is the emergency service including personalized priority assistance in case of sickness or other personnel emergencies, and, of course, in case of actual distress or imminent danger to the ship. Such emergency communications include both ship-to-shore and ship-to-ship service.

The Great Lakes radiotelephone system includes eight conversation channels in the 2–9-megacycle range, together with a short-range channel around 37 megacycles; there are also some channels in the 150–162-megacycle band which have been allocated tentatively by the Federal Communications Commission solely for marine use, but these have not as yet received final allocation.

In general, operating ranges are less over the fresh water of the Great Lakes than they are over the ocean. Five of the eight channels just noted in the 2–9-megacycle range are in the 2–3-megacycle portion of that band and are intended primarily for the shorter range daytime calls up to perhaps 200 miles. The remaining three are in the range of 4 to 9 megacycles and satisfy the requirements for longer range communication demanded by the peculiar configuration of the Lakes and the service requirements of Lakes shippers. Such long-range communication can be assured day and night, month after month, year after year, only by having all of these channels available, and every one of them is essential to good service and all are well loaded.

It may be interesting briefly to describe the various channels. They are numbered for convenience in selection, since the big majority of Lakes boats are equipped with dial-type channel selection facilities. Channel 10 is in the 8–9-megacycle band, channel 20 in the 6–7-megacycle band, and channel 60 in the 4–5-megacycle band; these three constitute the longer range facilities. They, with the shorter range 2–3-megacycle channels 30 and 39, are the "working" channels for ship-to-shore service; most vessels have either channel 30 or 39, but not both, since 30 is intended for large boats and 39 for smaller ones. The Canadians have their own channel, number 38, which is also in the 2–3-megacycle band.

These "working" channels may be connected, at the shore stations, into the land wire telephone system and are used for ship administration and personal calls by or to crew members as a regular land wire telephone would be used. In this connection, it may be interesting to know that one of the most important administrative uses of the "working" channels is in making and maintaining the close arrangements required between ships and the loading or unloading docks to avoid waiting time by the vessel or to insure properly timed arrivals of railroad cars since each boat will empty or fill from 130 to 300 railroad cars.

Another of the 2–3-megacycle channels is channel 40 which is devoted solely to ship-to-ship communications. Incidentally, there are two such channels on the oceans but only one is allowed to the Great Lakes. Still another of the five 2–3-megacycle channels is channel 51. This channel is primarily for emergency or safety calls; however, it also is used for voice calling between ships or for optional voice calling between ship and shore. In either of these cases the following conversation is conducted, respectively, on the ship-to-ship channel or on one of the "working" channels. All Lakes vessels are required to "monitor" or listen with a loud-speaker on channel 51 when they are not working on another channel. Channel 51 also is monitored by the United States Coast Guard, thus offering a common

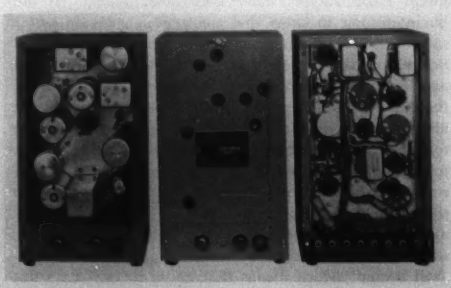


Figure 5. The radio receivers are crystal-controlled, one receiver for each of the six channels; the center view is of the receiver front with cover in place, the left view is front with cover removed, the right view is rear with cover removed

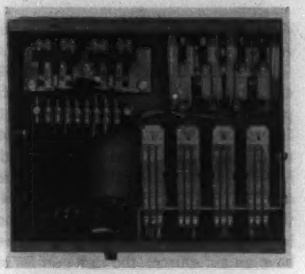


Figure 6. The ship's selective signaling response unit responds to selective calling signals from shore stations

medium between the Coast Guard and the Lakes vessels to facilitate emergency and general navigational co-operation.

As already noted, all of the "working" channels are designed to be extended, at the shore stations, into the wire telephone system. In order to do this satisfactorily for the myriad of telephone line characteristics which must be accommodated, the radio paths for the two directions of speech must be completely divorced; that is, shore-to-ship speech must be transmitted on one frequency and ship-to-shore transmission on another, these two separate frequencies together forming the "channel." As an example, channel 30 includes shore-to-ship transmission at 2,550 kc and ship-to-shore transmission at 2,158 kc. Such a separated-path 2-way channel is designated a "duplex" channel, as distinguished from a "simplex" channel in which speech is conducted in the two directions, alternately, over a single frequency. Both channel 40 and channel 51, the ship-to-ship channel and the emergency and calling channel, are of the "simplex" type.

Channel 51 is monitored by all ships and therefore may be used by the shore stations to call a ship by voice. However, practically all of the ship receivers are equipped with selective signaling provisions so that a shore station may call a ship directly on any of the various working channels, without bothering any other ship. When a vessel is called in this manner, its own bell, only, is rung; the call is not heard by other ships.

Two selective-signaling methods are in general use on the Lakes, and all shore stations are equipped to use either of these as required for the particular ship being called. The big majority of ships use a type which employs various tones in different permutations for which the ship's responsive equipment includes tuned relays or electrically tuned circuits. The second type is used by only a few vessels; it is of the dial-controlled type in which two tones are transmitted in immediate succession, each dial "pulse" being actually the change in tones. The corresponding ship receiving equipment includes a special type of stepping switch, which adds up all of the "pulses" for all of the several dialed digits, providing its particular setting corresponds to the particular digits which were dialed; otherwise the special stepping switch drops back on each "wrong" digit.

Every Great Lakes radiotelephone system channel is a mammoth party line with several hundred parties on it. Wire party lines seldom have more than four parties on them; consider the Lakes radiotelephone "party lines" with their several hundred "parties" and you will agree that tribute is due the courtesy and co-operation of the Great Lakes ships' officers who use their radio party lines month after month with an astonishingly small amount of friction.

Since the Great Lakes radiotelephone system differs markedly from the coastal-harbor systems on the coast, it is fitting that the ships' radio equipment be different also. The greatest difference between the radio equipment used on coastal and on Great Lakes vessels is in the necessity for the Lakes ship receiver to "ride the air" or monitor all of four working channels plus the emergency and calling channel, at the same time, so as to allow the ship to be called directly on any channel at any time. This requires at least five separate and complete radio receivers, all of which must be an integral part of the ship's radio equipment.

In the Great Lakes system all of the channels are numbered, and the system is so set up that the ship's officers may use their radiotelephone just as they would the familiar land line telephone; thus they may dial up a channel as they would a number on a land line telephone. This does not, of course, preclude use of a ship set having other methods of channel selection as desired, but most of the United States ship equipments use the dial, and in any case the universal designation of each channel by a number simplifies radiotelephone use by the ship's officers, to whom the radiotelephone is an every-day working tool.

The typical ship radiotelephone set for Lakes use has a nominal power output of 50 watts. It provides for six channels—all of the channels normally required by any one ship—and has six separate receivers. This radiotelephone set works day in and day out over the 600 or more miles between western Lake Superior and *WMI* at Lorain, Ohio which may surprise those who are accustomed to think in terms of higher power for such distances. The illustrations show the ship radiotelephone set made by The Lorain

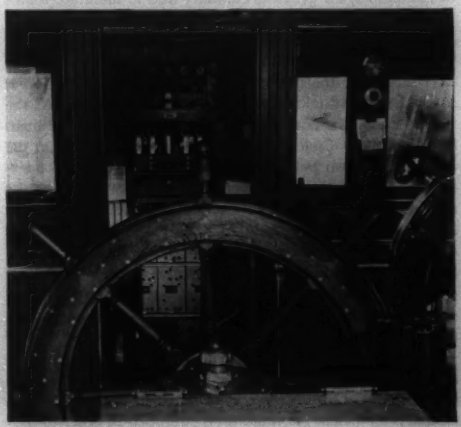


Figure 7. A typical installation on a Great Lakes vessel

The radiotelephone set is in the chartroom aft of the wheelhouse

Figure 8. A desk-type control subset

The user initiates a call by dialing the desired channel; he answers a call by dialing the channel indicated when the call is received

County Radio Corporation, but they are broadly typical of some equipments made by Western Electric Company and Radio Corporation of America. Such sets are used by practically all of the commercial vessels on the Lakes.

Tampering is prevented by putting the set in a locked cabinet with no accessible controls; such obviously important protection is possible against thoughtless human nature since the set is entirely remotely controlled and thus requires no access by the user. The cabinet generally is mounted in an out-of-the-way location. Figure 2 shows the inside of the cabinet; the door has been removed to give a better view of the equipment.

Figure 3 shows the radio-frequency chassis located on the top shelf in the cabinet. This chassis contains the multichannel radio oscillator and the radio power amplifier; it includes the associated tuned circuits for the various channels, and the relays which eventually select the desired channel under the control of the dial on the subset unit shown in Figures 8 or 9. Separate tuned circuits are provided for each channel, for greater reliability and to facilitate maintenance.

Figure 4 is the modulator and control chassis, located on the second shelf in the cabinet. It mounts the voice amplifiers including the modulator. Amplitude modulation is applied in the final radio amplifier plate circuits. At the front, behind the horizontally hinged door above the jacks, are a number of telephone-type relays which interpret the channel-selection pulses from the dial and eventually operate the proper transmitter channel selective relay on the shelf above; they also select the proper receiver for the desired channel. Other relays on this chassis provide the voice-controlled switching which puts the transmitter "on the air" when the user speaks and takes it off the air when he stops speaking, thus simplifying use of the radiotelephone system by eliminating the otherwise-necessary talk-listen key in the handset handle.

Figure 5 shows a typical radio receiver, of which there are a total of six located on the third and fourth shelves in the cabinet. One receiver is provided for each of the six channels for which the radio set is equipped in order to permit simultaneous monitoring on all "working" channels as well as on the emergency and calling channel, number 51. The ship-to-ship channel, number 40, is not monitored during standby but has a separate receiver for reliability and easier maintenance.

At the bottom of the cabinet (Figure 2) is the power supply equipment. Most of the Great Lakes ships have 110-volt d-c power sources. The dynamotor at the lower left converts the 110-volt d-c supply to approximately 500 volts for the transmitter tubes; the filters and automatic controls are at the lower right. Incidentally, the radio receivers are supplied directly from the ship's 110-volt d-c source, thus avoiding the necessity for operation of any dynamotor or other rotating machinery during standby. A few of the Lakes vessels have an a-c source; the radio set for such boats includes a suitable electronic rectifier instead of the dynamotor shown in Figure 2.

Figure 6 pictures the selective signaling response unit. It is habitually mounted on the inside of the cabinet door, and includes all of the equipment required for response to the selective calling tones transmitted by the shore stations to call a desired ship directly on the working channels. The mechanically tuned relays are in the upper left corner, each mounting two reeds tuned to different audio frequencies; their driving coils are fed, during standby, from the paralleled outputs of the "working" channel receivers. The relays at the lower right are operated successively on response of the appropriate tuned reeds and eventuate in a bell signal if the received tone signals are of the proper frequency and in the proper order for which the particular unit is preset.

Figure 7 portrays a typical installation on a Great Lakes vessel, showing the forward part of the wheelhouse looking aft into the chart room, where the cabinet is located in this case.

Figure 8 shows a typical desk-type control subset; it looks in every respect like a regular office telephone subset. It is used similarly by the ships' officers. Talk-listen switching is controlled automatically by the user's voice, which eliminates the familiar push-to-talk key in the handset handle. To initiate or answer a call, the user dials the first digit of the desired channel number and then listens to be sure the channel is not already in use. If the channel is

Figure 9. A wall-type control subset widely employed in the wheelhouse or other locations where a desk type is inconvenient

clear, he then dials the second digit and is ready to proceed with the conversation. The box associated with the desk-type control subset contains the loud-speaker and its volume control for continually monitoring the emergency and calling channel during standby, in accordance with the Federal Communications Commission's requirements. This box also includes the bell which signals a call to that particular ship from a shore station; incidentally, the bell signal not only indicates a call but it also indicates the "working" channel on which the call is coming, by means of a coded repetition of the last tones in the selective calling signal.

It also may be of interest to know that the ships all call the desired shore station by voice, either directly on a "working" channel or on the calling and emergency channel 51, as desired. Whenever a ship dials up a "working" channel to make a call, a momentary tone is sent out which warns the shore stations that a call is being initiated.

Figure 9 is a wall-type control subset often used in the wheelhouse or chart room instead of the desk-type subset just shown. It includes everything—handset, cradle-switch for the handset, dial, loud-speaker and its volume control, and the signaling bell.

Safety in Machine Tool Control

D. K. FROST
MEMBER AIEE

With the ever-increasing use of complex machinery, the subject of safety, both of personnel and of the machines themselves, assumes greater importance. Although faulty control is probably a minor cause of accidents, so long as it is responsible for even a small percentage it requires the best efforts of engineers in the development of the necessary safety features.

ELECTRICAL control in machine tools has been well styled the "brains" of the machine, but even so, safety features have taken on added importance as semiautomatic and fully automatic machines increase in number and in complexity.

Statistics reveal that death tolls in 1947 from "on the job" occupational accidents were 17,000, an increase of 500 over 1946. There were 2,050,000 nonfatal injuries including 90,000 that resulted in some permanent impairment. The percentage of these chargeable to faulty control is probably small. It is reasonable, however, that even a small percentage requires the best efforts of engineers on safety features.

In this article the subject will be considered not alone from personal safety, but also from the standpoint of safeguarding the useful life and operation of the machine.

The electrical hazards are those inherent in the use of electricity for power, light, heat, control signalling, and other purposes. Other hazards arising from functions of the machines which may be dangerous to personnel, the machine itself, or to the work in process will be discussed also.

Reference is made to the "Machine Tool Electrical Standards." This code first was written by an electrical committee of the National Machine Tool Builders' Association in 1935 and 1936. Lately it has been revised and accepted for general industrial use. The usage of this code has done so much to improve the quality of wiring practices and devices used, that it has been a notable factor in increasing the safety of machine tool control. These advances were made quite apparent at the recent Machine Tool Exhibit in Chicago, Ill.

It is significant that this code is largely responsible for the use of lower and safer voltages for control circuits. The use of 110-115 volts is now quite universal, the same as it is for practically all lighting circuits. Where used on control circuits, it is derived from transformers of from 300 to 1,500 volt-ampere capacity. Obviously the use of comparatively small output transformers, protected by circuit breakers or fuses in one or both sides of the output circuit, is a good safety feature. The transformers are designed with low reactance and limit the terminal voltage drop to a minimum even with peak loads of 400 to 500 per cent. They also are provided with dependable insulation to isolate the low-voltage control circuit from the higher voltage power circuit. The short-circuit output is small, thus minimizing fire hazards and reducing danger to personnel.

The use of voltages lower than 110 volts is quite prevalent for bells, horns, and signal lights. Circuits of 12 or 24 volts is common practice. On multimotored machine tools such low voltages are disadvantageous, because there is not enough pressure to break through corroded contacts where there are a number of such contacts in series. These low voltages invariably lead to trouble over long periods of time.

Another safety measure avoids short circuits by placing all push buttons, limit switches, and other control accessories in one side of the control circuit, so there cannot be

Full text of a conference paper presented at the AIEE Midwest general meeting, Milwaukee, Wis., October 18–22, 1948.

D. K. Frost is an electrical engineer, Mattison Machine Works, Rockford, Ill.

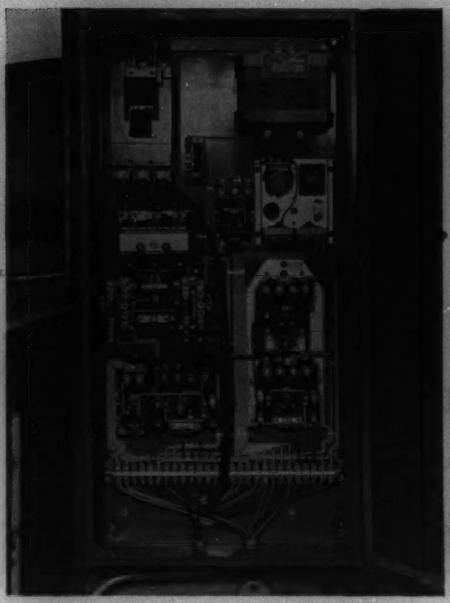


Figure 1. Enclosed panel with 100-ampere disconnect circuit breaker and door interlock for surface grinder

Also shown is the 500-volt-ampere control transformer—10-ampere control circuit protective breaker and control for five motors

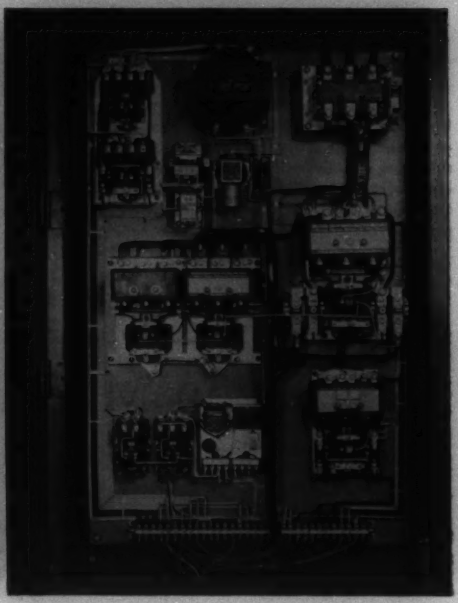


Figure 2. Enclosed panel with 200-ampere disconnect circuit breaker and door interlock for large surface grinder

Also shown is the Y-delta starting and electronic timer which is used for control of cross feed

two points of opposite polarity adjacent to each other in any such devices. The only effect of accidentally connecting two points together would be to cause faulty operation.

Another practice is to have all control switches assembled in one enclosure with disconnect switch or circuit breaker that disconnects all power circuits to the machine at this one point. The switch or circuit breaker is part of the control panel and mechanically or electrically interlocked with the control enclosure door handle (Figures 1 and 2).

These panels are arranged so that authorized electricians can open the door and watch the control function while the machine is operating for trouble shooting but prevent an unauthorized person from opening the door when the switch or circuit breaker is in the "on" position.

The enclosure itself must be dusttight and mounted so that the control will not be exposed to metal dust, coolant, or oil. Insulating materials break down and lose their insulating qualities where subjected to mechanical injury, liquids such as oil and collants, along with abrasive and conductive dust. For protection against these hazards all conductors are enclosed in rigid or synthetic-rubber-covered metal-reinforced flexible conduit especially made for this use. The conductors themselves are insulated with oil and moisture resistant thermoplastic insulation not less than 3/16 inch stranded for all runs through conduit and solid or stranded on the control panel.

These features and others in the code are commonplace in the machine tool field and well might be extended to all types of industrial machinery. Some companies are extending these practices into the woodworking machinery field also, with exceptionally good results at only relatively small increase in cost.

The hazards from functions of machines varies with each type of machine, however all have some functions in common. Every machine which has any potential danger from starting unexpectedly should have means of preventing such a hazard. A great help in attaining this result consists of a walking beam type of "on" and "off" switch usually called a "master" station. It is inexpensive and simple; however, in the average shop not more than one out of four machines have this fundamental means of safety.

The contacts of such a station break the control circuit at its source. This isolates the machine control as far as operating magnetic switches electrically is concerned. The "master" station only closes the control circuit. It does not start the machine or any function of the machine. On especially hazardous machines a buzzer or signal light indicates that the "master" station has been closed giving warning to workmen who might be near or working on the machine.

Another function that machines have in common is that

they must stop safely under the following conditions:

1. Incorrect sequence of operation.
2. Tripping the final limit switch.
3. Overload.
4. Power failure.
5. Stalled motor or motors.

Many examples could be given as to why it is important to stop machines safely. It is obvious, for instance, that if the main drive or drives should stop and the feed continue to run, a machine can be wrecked or cutterheads broken or spindle sprung.

If magnetic chucks are used and d-c power in the chuck circuit fails, the cutter or grinding wheel must be stopped quickly to prevent injury to operators or machines.

The "purely electrical" forms of braking might be classified as:

1. Dynamic braking.
2. Regenerative braking.
3. Plugging to stop.

Dynamic braking usually is associated with d-c motors, and used either with or without a solenoid-operated brake gives a very effective stop. On alternating current, plugging to stop is quite effective, but on high-inertia loads the usual methods would involve resistors in the plugging circuit. Y-delta reduced voltage plugging works out very well.

On a-c motors, dynamic braking can be provided by having a separate source of direct current connected to one phase of the motor primary. Direct current also can be obtained by means of rectified current, from a rectifier of the dry disk type which receives its power from the normal a-c supply. The braking torque with these systems increases as the motor slows down and provides a smooth positive stop that will not reverse the motor. However, the braking connections must be broken after the braking is completed.

Figure 3 shows a 40-horsepower 1,800-rpm totally-enclosed fan-cooled ball-bearing motor with a combined shoe and disk-type electric brake operated from 90 volts direct current, derived from 110-volt a-c control transformer circuit by means of a silenium rectifier stack shown on the panel in Figure 4. The braking time with a high-inertia load of approximately six times the WR^2 of the rotor itself can be varied from 5 seconds to 30 or 40 seconds by means of a rheostat in the 90-volt d-c circuit. This rheostat also is shown in Figure 4.

This brake has proved to be very effective and compares favorably with variable dynamic braking as used with d-c motors of the same rating and speed.

There are many methods of braking a-c motors; some of them brake too rapidly at first and then lose their effectiveness at the lower speeds, some are too sluggish at the higher speeds and more effective at low speeds. Moreover, they are not readily adjustable for time of stopping. It has been found that on direct current the most effective brake is adjustable dynamic braking with a solenoid brake for the slow speed end. On a-c braking the electric brake described gives the best result obtained up to the present.

A few specific examples of hazardous machines will be cited, along with the methods used for attaining safety in operation.

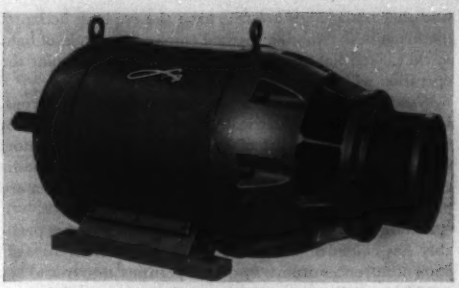


Figure 3. A 40-horsepower 1,750-rpm enclosed fan-cooled ball bearing motor with combined shoe and disk-type electric brake

Many types of grinding machines are hazardous, especially those employing magnetic chucks for holding the workpieces. One source of danger is the failure of direct current to the magnetic chuck thus releasing the workpieces which are held only by magnetic lines of force. A method endorsed alike by manufacturers and users of surface grinders is to use a separate motor generator set for each grinder. This insures that the operator is certain of his source of power supply. In case of sudden failure of power the generator of the set, which sometimes is provided with a small flywheel, will have enough residual magnetism in the fields to generate enough voltage to keep the chuck magnetized before the set comes to rest. By that time the grinding wheel will have slowed down so that the wheel cannot throw the workpieces dangerously.

All types of power presses, shears, punches, and benders are hazardous. Effective electric devices consist of push buttons so located that each hand operates a button to in-

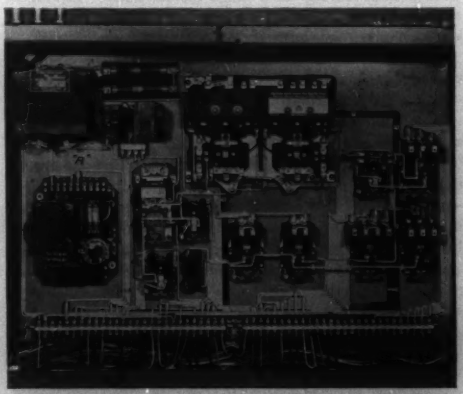


Figure 4. Enclosed panel for number 455 sheet grinder showing on subpanel "A" selenium rectifier stack and adjustable rheostat for obtaining variable braking time on 40-horsepower motor shown in Figure 3

sure that both hands are free from the crushing action of the machines. Another method employs a curtain of light so that if the light beams are obstructed at any point the operation will stop.

Woodworking machines are particularly dangerous. Up to the advent of electrically driven machines it was not unusual to find one out of every three or four operators with one or more fingers missing. Now where it is possible to insure better against accidental starting, not more than one out of 20 has such accidents to his hands.

Failure of contacts in relays and magnetic switches probably has caused more fatalities than any other hazard. Such occurrences ordinarily do not permit safeguards to act quickly enough to prevent damage to machines or injury to operators. The use of silver elkonite contact tips on air brake and copper elkonite on oil-immersed switches have had excellent results where sticking is a serious problem. Other combinations of carbon and copper have proved effective.

The cause of failure of contacts in many instances probably results from lack of proper maintenance, the tips not being replaced when they have lost their follow up or are worn so thin that they have lost their effectiveness. On the other hand, as yet there are no specific data on the probable life expectancy of contact tips. Because of several serious accidents, one company has made it a rule to replace tips on switches in constant use at least every year, even though the life expectancy is many millions of operations. In the past few years there has been a tendency to order spare movable and stationary contacts with new equipment, and also a tendency towards furnishing packaged spare contact tips. If this were more general, then failure of contacts would decrease and insure safer control equipment.

Adequate grounding of machine tools has not been practiced to the extent it deserves. For years we have made it a practice to bolt a copper lug to the machine frames after removing paint and dirt from the joint surfaces. The size of the grounding conductor is covered by a table in the code. Where the main circuit breaker is 100 to 200 amperes capacity, the correct copper wire size is number 8 and number 6 respectively. Grounding of stationary and portable equipment is covered fully in the machine tool electrical standard specifications. It is an important item but it is an item which very frequently is disregarded.

Electric equipment will operate with maximum efficiency and safety only when used for the purpose and under the conditions for which it was designed. Installations and operation should comply with applicable codes and standards. The results have justified and will continue to justify such procedure.

Radio Detects Meteor Speeds

Meteor speeds can be determined with good accuracy by a new, simplified radio detection technique. Measurements made during the Perseid meteor shower in August 1948 gave an average speed for the shower meteors of 39.6 miles per second, which is within 2.6 per cent of the value determined by astronomical methods. Sporadic meteors were also "clocked," and found to vary from 12 to 43 miles per second.

The meteors were studied by means of a continuous high-frequency radio wave directed at the sky. Each particle of cosmic dust striking the ionosphere creates an intense disturbance, resulting in the formation of a large column of invisible ionization which reflects radio energy. Waves reflected from the head of the column, which has been found to move at the same speed as the meteorite, suffer a Doppler shift in frequency which is readily measurable.

The Doppler shift is the effect which causes the pitch of a locomotive's whistle to be higher when it is approaching the listener than when it is receding. The pitch, or frequency of the radio wave reflected from the nose of the meteor column suffers a similar shift due to the meteor's motion. Each meteor may be heard in a pair of earphones connected to a radio receiver as a brief tone of descending pitch, resembling a cosmic "wolf whistle."

Unlike radar detection methods, which call for high-power, complex equipment and require a considerable band-width in the radio spectrum, the new system employs a radio transmitter no more powerful than those used by many radio "hams." The channel-width required is negligible. The heights of shower meteors also may be determined by an extension of this method. Heights of the Perseid meteor reflections were found to vary from 88 to 50 miles above the earth, as the radiant elevation rose from 25 to 45 degrees. This measurement is potentially more accurate than combined radar and photographic height determinations.

Far more meteors may be analyzed by radio than by optical or astronomical means. The radio "camera" is over 100 times as sensitive as the human eye, and is perhaps 10,000 times as sensitive as the special cameras used by astronomers. Study of radio meteor reflections is yielding new information on the composition of the upper atmosphere. The rate of growth and dissipation of meteor ion clouds sheds new light on the physical behavior of the rarified gas through which rockets—and someday space ships—must travel. Prediction of radio transmission conditions is also expected to benefit from these studies when they are used to record the ionosphere's reaction to intense local disturbances.

Evolution of Shovel and Dragline Control

P. S. STEVENS
ASSOCIATE AIEE

THE FIRST ELECTRIC shovels were equipped with rheostatic control with both d-c and a-c motors and date back to 1902. A shovel presents a variety of problems to tax the ingenuity of the motor and control application engineers. For example, a shovel hoist adds to the usual mine hoist problems, the requirement of stalling under load without interrupting motor torque.

In the shovel industry "Ward-Leonard" designates a d-c motor-driven unit controlled by its own individual generator. The first Ward-Leonard shovel, sold in 1919, had differential series generators to stall the motor. This characteristic has proved a more effective and permanent means of stall limitation than the "notch-back" relays used with earlier rheostatic controls. The differential field produces the desirable steam engine characteristic.

At first, series motors, carried over from rheostatic control because of their good digging characteristics, were used with Ward-Leonard control, but they were not effective for braking and dipper lowering, and were superseded later by separately excited shunt motors. To the original generator control shunt field and differential field, a self-excited generator shunt field was added later to raise digging speeds to be comparable to steam practice. This gave the shovel the well-known 3-field generator, which, with later improvements in motor and generator design, raised the no-load voltage from 330 volts to the present standard 575 volts, applied to normal 230-volt motors.

Fairly satisfactory operation with series motors was accomplished, but required heavy contactors, resistors, and other control gadgets, in spite of which the operation was rough on commutators and machinery. In the repetitive short cycle operation of a shovel, braking and decelerating are almost as important as accelerating and pulling. To meet these requirements the shunt-type motor offered better characteristics and simpler control. The first completely shunt motor equipped shovel began operation in 1925 as a seven cubic yard coal loader in Montana.

Shunt motors gave such complete and smooth control as to permit lowering the empty dipper on the motor without declutching the prime mover and catching the falling dipper on a mechanical brake as was the practice with steam shovels. Motor lowering had been used on six to eight cubic yard a-c motor-driven stripping shovels as early as 1917. However, it was not until 1925 that a close-coupled fast-cycle shovel was designed for motor lowering with Ward-Leonard control. Up to this time electric shovels were in reality electrified steam shovels. A four cubic yard machine was the first real electric shovel designed without an operating clutch and without a large lowering brake. Motor lowering proved less tiring to the operator and easier on the entire machine, and has become practically universal.

With the control problem solved, attention then was focused on the flywheel effect of the motors. Faster cycles resulted from the 4-yard shovel with a new hoist motor having a WR^2 of 437 instead of the original motor with 1,040.

The characteristic of the shunt motor to continue its controlled overhauling speed even if the torque reverses, permitted the use of a counterweight to help hoist the dipper. The balanced hoist appeared in 1930 on a 16 cubic yard shovel. In addition to the commonly known advantages of safety and a smaller motor as experienced on elevators and mine hoists, there are other benefits from the counterweight on the shovel such as, faster cycle, more desirable power load, reduced power bill, and longer insulation life. On a large shovel, two 250-horsepower hoist motors with a balanced hoist will equal the pulls and speeds of two 425-horsepower motors without balanced hoist, and will produce a faster cycle because the flywheel energy of the smaller motors is less than half that of the larger motors.

Ward-Leonard control proved so effective that independent motors now are used on large draglines for drag and hoist drums. Heretofore both drums were driven with the same motor through clutches, with foot brakes for holding and lowering. The year 1942 saw the first large dragline, a 25 cubic yard machine, go into operation in Illinois with independent motors. In spite of a considerably higher first cost, independent drive has spread to smaller draglines, even to the eight cubic yard size.

Early Ward-Leonard shovels experienced an excess of bail pull when starting up cold in the wintertime. In northern climates this was serious because most steels are weaker at low temperatures. Today equipments give approximately uniform motor torques at variable temperatures.

Large shovels and draglines are equipped today with what generally may be termed "rotating control" in connection with the Ward-Leonard application. The combination produces a faster response of the large generators to the needs of the operator.

It seems certain that any form of power transmission to compete with Ward-Leonard drive for shovels must provide for power braking, as it has been a great relief to both user and manufacturer to be free of the problems connected with large heavy duty mechanical brakes and clutches. Ward-Leonard control with its regenerative braking characteristic has done the job so well that it seems to be safely entrenched for some years to come on large excavating machines.

Digest of paper 48-269, "Evolution of Ward-Leonard Control for Shovels and Draglines," recommended by the AIEE mining and metal industry committee and approved by the AIEE technical program committee for presentation at the AIEE Midwest general meeting, Milwaukee, Wis., October 18–22, 1948. Scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

P. S. Stevens is with the Bucyrus-Erie Company, South Milwaukee, Wis.

Interconnected System Load-Frequency Control

H. M. DIMOND
ASSOCIATE AIEE

G. S. LUNGE
ASSOCIATE AIEE

IF ALL TIE LINES were of ample capacity and stations under automatic control were well distributed geographically, there would be no need for tie line control except where required by contract interchange schedules. With the large scale advent of system interconnections and the necessity for more efficient operation, the tendency is to use frequency control biased by tie line load rather than frequency control only.

The most common type of frequency control responds to instantaneous frequency difference with corrective impulses readjusting the prime mover speed level setting at a rate at least approximately proportional to the deviations from standard frequency. The frequency-responsive device for this type of equipment is usually an a-c bridge circuit or sometimes a pendulum-type clock in which corrective signals can be sent out for each swing of the pendulum.

To obtain the advantage of smoother and less rapid prime mover gate or valve operation under automatic control, a system has been designed to use a tuning fork source of standard frequency instead of a pendulum. A differential Selsyn then is used to compare the system frequency continuously with this standard and provide a continuous smooth correction rate proportional to the integrated frequency error. Such a continuous comparison eliminates any dead band in the controller, as even a very minute drift in frequency is perceived by the differential Selsyn. In its original form the continuous type of integrated deviation frequency controller did not take into consideration the tie line loading but more recently this feature has been added.

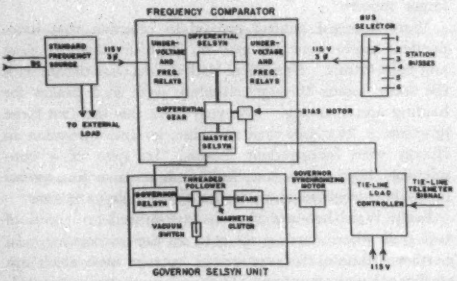


Figure 1. Block diagram, frequency and tie line load control system

The tie line load controller has been designed to cover a very wide range of requirements so that the equipment may be operated with nearly any biasing combination of frequency and load control. It has an adjustable dead band to allow minor inevitable load swings to take place without change of the prime mover governor settings.

The latest concepts of efficient power interchange methods were carefully considered in it's design. Figure 2 shows a block diagram for the frequency and tie line load control system developed to meet these specifications. The system consists of a standard frequency source, a frequency comparator, a means for transmitting the signal from the frequency comparator to the governor control, a tie line controller, and a means for converting this tie line load controller signal to a form which can be used to bias the frequency control signal. The continuous-comparison load-frequency control equipment has the following novel features as compared with earlier equipment operating on the same integrated frequency-deviation principle:

1. Standard reference frequency is a tuning fork controlled source, instead of pendulum-established.

2. Comparison between system and standard frequencies is continuous and results in a proportionate correction in prime mover governor adjustment.

3. Tie line bias, in adjustable amount, now is included.

4. The tie line load controller can operate either on flat tie line control or tie line bias control.

5. The tie line load controller continuously compares the tie line loading, measured locally or telemetered, with its scheduled value, but only initiates proportional correcting action in case of deviations outside the adjustable dead band.

6. Instead of raise or lower impulses, the load-frequency control equipment originates a continuous proportional correction for the governor Selsyn units, thus making less rapid changes in governor adjustment necessary to accomplish the same resultant change in speed level setting.

7. By telemetering the tie line load deviation from schedule to several generating stations each containing load-frequency control equipment, several stations can be regulated simultaneously.

8. There is no dead band for frequency deviations from schedule, even slow drifts in frequency being detected and eventually corrected.

9. There is no need for bringing a measurement of each controlled generating unit output to the load-frequency control equipment for verifying load division.

10. Time error is corrected automatically daily, as long as the controlled generating units remain within their regulating range. Slight differences between astronomically correct time and tuning fork standard time must be correct manually.

11. Load division between simultaneously controlled units is automatic, requiring no supplementary equipment, as long as the permissible regulating range of each unit is not exceeded.

Digest of paper 48-268, "Continuous Load-Frequency Control for Interconnected Power Systems," recommended by the AIEE system engineering committee and approved by the AIEE technical program committee for presentation at the AIEE Midwest general meeting, Milwaukee, Wis., October 18-22, 1948. Scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

H. M. Dimond and G. S. Lunge are both with the General Electric Company, Schenectady, N. Y.

Digests of Papers Presented at Electric Welding Conference

These are authors' digests of most of the papers presented at the AIEE conference on electric welding, Detroit, Mich., December 6–8, 1948. The papers are not scheduled for publication in AIEE TRANSACTIONS or AIEE PROCEEDINGS, nor are they available from the Institute.

The Nature of the Arc; *J. E. Cobine (General Electric Research Laboratory, Schenectady, N. Y.).*

The short high-pressure heavy-current arc, which is called the "welding arc" for convenience, burns in a gas mixed with metal vapor from the electrodes. The column of the heavy current arc is considerably constricted from the low current value by the magnetic effect so that the current density may be as great as 3,000 amperes per square centimeter. The gas in the column is at a very high temperature, ranging from 5,000 degrees Kelvin to 7,000 degrees Kelvin, with evidence of much higher values. Polyatomic molecules such as N_2 and O_2 are largely or completely dissociated. The conductivity is maintained by thermal ionization with Saha's equation applying with an uncertainty in ion density of not more than about 20 per cent.

At the cathode end of the column is an extremely important and poorly understood region, known as the cathode drop region and where the cathode spot is located on the surface of the electrode. The cathode spot is the point of current transfer and the cathode drop region is the space in which energy conditions are established to make that transfer possible. The theory of electron emission is satisfactory only for tungsten and carbon rods. For these materials the electrons are emitted thermionically with a current density of a few hundred amperes per square centimeter. Until recently the current density at the cathode spot of low boiling point metals (iron, aluminum, copper, and so forth) was believed to be of the order of 4,000 amperes per square centimeter. In a recent study it was found that a more probable value was 50,000 amperes per square centimeter or more, that is, at least in order of magnitude higher than was supposed. One method of determining the current density at the cathode spot consisted in measuring the tracks left by the spot on metal surfaces. At currents above a few amperes the tracks show a very branched structure, as though the "spot" consisted of a cluster of small spots all racing wildly about. The effect is very pronounced for aluminum. The spot phenomena appears to be definitely associated with the presence of oxide layers or similar films on the electrode surface. It is impossible to maintain a stable arc on low boiling point metals in an inert atmosphere unless some oxide is present. This effect has been observed even on tungsten sheet.

Current densities of the high magnitude observed cannot be obtained from low boiling point metals by thermionic emission unless the cathode spot is at more than twice the boiling point. This has not been established, although it is believed by some authorities. The field emission of electrons, which has seemed a possible mechanism for these "cold" electrode arcs, appears incapable of supplying these high current densities.

The emission of electrons by oxide layers appears very important, although the mechanism is not clear. The collection by the cathode of sufficient positive ions to make up the current without any electron emission also has been suggested. The high degree of ionization required for this mechanism might come from a great constriction of the column.

The anode electrode is heated by the incoming electrons which are accelerated by an anode drop that may be of the order of the ionization potential. This electrode is heated more than the cathode since the emission of electrons from that electrode has a cooling action whereas the "condensation" of electrons heats the anode.

New Observations on Welding Arcs; *Lauriston P. Winsor (Rensselaer Polytechnic Institute, Troy, N. Y.).*

The welding laboratory at Rensselaer Polytechnic Institute has been engaged for some time in an investigation of welding arc stability sponsored by the Bureau of Ships of the Navy Department. The primary objectives have been the development of instrumentation for quantitatively evaluating the stability of the d-c welding arc and the application of such instrumentation to a study of some typical welding arcs. The work has been based on the assumption that the stability of the welding arc can be evaluated in terms of fluctuations in arc current and voltage, and occurrence of short circuits. Various methods for evaluating arc stability have been investigated including statistical analysis of oscillograms, use of the Arcronograph, and determination of arc power factor. The method which finally was adopted for the current work involves the use of electronic circuits for determining rms values of the fluctuating components of arc current and voltage, and for counting short circuits. These circuits are supplemented by recording instruments for measuring the average values of arc current and voltage. By means of this equipment and a mechanical welding head the performance of a number of different types of commercial electrodes has been investigated. The results reveal the nature of the relations among the rms deviations in arc current and voltage, the average values of arc current and voltage, and the occurrence of short circuits. At present the chief problem is to determine the significance of these relationships from the point of view of arc stability. Toward this end, the electrical measurements have been supplemented by observations of arc length, spatter loss, and penetration of fusion in the work. An incidental result of the investigation has been the observation that, for a constant voltage across the welding arc, the arc length varies inversely with the magnitude of the arc current. This is contrary to what has been observed in low current arcs. A few high-speed motion pictures of the welding arc have been taken with both color and infrared film in connection with the project.

Burn-Off Characteristics of Steel Welding Electrodes; *D. C. Martin, P. J. Rieppel, C. B. Voldrich (Battelle Memorial Institute, Columbus, Ohio).*

In electric metal-arc welding, a high-current arc is maintained between a metal electrode and a work piece to be welded. The electrode is consumed continuously by fusion of the tip and a small volume of the work piece is melted by the heat of the arc as it passes along the weld joint. The melted metal at the tip of the electrode is transferred across the arc, deposited upon, and fused with metal of the work piece. The arc characteristics, in general, of metal-arc welding are influenced broadly by the electric circuit, and by the ingredients of which the welding electrode is made and, to a minor degree, by the material being welded. Outside of the electric circuit it is thought that this depends principally on the way in which the metal transfers from the electrode across the arc to the work piece. The character of metal transfer, in turn, is influenced considerably by the rate at which the tip of the electrode is melted or is "burned-off." Thus, the usability of metal-arc welding electrodes, the quality of the welds, and the rate at which welds can be made depend greatly upon electrode burn-off rates.

Considerable information on electrode burn-off has been accumulated in studies of the metal-arc and of welding electrodes. It has been shown that various types of bare and coated electrodes of the same wire diameter may be different in burn-off rate though used under the same welding conditions while a pronounced effect is produced by changing the electrode connection from the negative to the positive side of the d-c welding circuit.

It has been demonstrated that the addition of a relatively small amount of a single ingredient to an electrode coating changes the burn-off rate of the electrode when all welding conditions remain constant. The fundamental factors which cause the differences in burn-off rates that are associated with coating ingredients are not completely understood. It is known that coating ingredients have an influence on welding factors such as the surface tension of molten metal at the electrode tip, arc-atmosphere composition, arc voltage, arc stability, weld-pool action, and spatter loss.

Information obtained from studies of bare-wire electrodes show that bare electrodes made of incompletely deoxidized steel (rimmed steel) burn off at much lower rates than highly deoxidized steel (killed steel) electrodes of the same diameter and nominal chemical composition, when tested under similar conditions. Rimmed-steel electrodes from different heats of steel of the same nominal chemical composition burn off at different rates under identical welding conditions. The burn-off rates of electrodes made from different parts of the same heat of steel are often different.

The arc-outage counter, developed specifically to study characteristics of welding

electrodes, measures the number of times that the arc is short-circuited out per minute during welding with bare and coated electrodes. The number and duration of arc outages reflects the operating characteristics of the electrodes.

Introduction to Inert Atmosphere Arc Welding; *H. T. Herbst* (*The Linde Air Products Company, Newark, N. J.*).

By definition the inert atmosphere arc welding process embraces electric arc welding in which the electrode, the arc, and the weld puddle are shielded by a continuous flow of inert gas.

Two types of electrodes in inert atmosphere arc welding are the consumed and the nonconsumed electrodes. The form in which the process now enjoys widespread use in industry employs the nonconsumed tungsten electrode. Another form now undergoing extensive test work makes use of a welding rod electrode. In this method the arc is drawn between a welding rod and the work as in the manual metal-arc welding process.

Both alternating and direct current are used with the inert atmosphere arc welding method and each type of current has particular advantages for certain metals. Straight-polarity direct current produces a rapid means of heat input and commonly is employed for the welding of stainless steel, carbon steel, copper and its alloys, and many other metals. Use of direct current in this process offers no unusual power supply problems not encountered in metal-arc welding. In general, sources of direct welding current suitable for metal-arc welding are found to be quite satisfactory for inert atmosphere arc welding.

A-c welding finds particular favor in the welding of aluminum and magnesium and thin gauges of other materials. Stability of the arc in a gas atmosphere is found to be a much greater problem than in the metal-arc atmosphere employing electrodes having flux coatings containing stabilizing agents. For this reason electrical problems are encountered in stabilizing the inert atmosphere arc not encountered in metal-arc welding as it now is practiced. Special transformers have been developed and are used for this process.

Features of the inert atmosphere arc welding process which adapt the process to certain types of welding are the ability to weld most metals without flux, the ability to control the shape and size of deposited metal, and the combination of high heat input rate with an extremely low degree of porosity. These features make the process applicable to the welding of many materials where flux removal is a problem. It also makes the process particularly applicable to the fabrication of those weldments which must be ground to a high degree of surface finish. The high rate of heat input and the high degree of density of the welds make the process applicable to the fabrication of large, thin sections which must be held to close tolerances and which, when polished, must exhibit no holes in the weld area.

Both hand and machine methods of operation are in common use. Both types of operation are carried on either with or without filler metal as conditions require. To a large degree the material being welded will determine the type of current to be employed.

In order to select the best type of welding current for particular metals, the characteristics of the inert gas arc may be explained on the basis of electrode polarity. In d-c welding, the electrode may be either negative or positive, while in a-c welding the electrode is, of course, alternately positive and negative.

Some Problems in Argon-Shielded Metal-Arc Welding of Thick Aluminum Plates; *R. D. Williams, P. L. Mirolo, C. B. Voldrich* (*Battelle Memorial Institute, Columbus, Ohio*).

During the past few years much interest has developed in the welding of thick wrought aluminum plate, and for this welding the argon-shielded metal-arc process, using tungsten electrodes, has been outstandingly useful. Although the process has several advantages over others that were applicable, many problems nevertheless were encountered, some of which still exist. This discussion pertains to those of particular significance in thick-section welding. Electrical problems will be considered primarily.

Most of the welding has been with the argon-arc process on *2S* and *3S* (nonheat-treatable) and *61S*, *24S*, and *75S* (heat-treatable) aluminum plates, 1/2 to 2½ inches thick, using commercially available filler rods, 1/8 to 5/16 inch in diameter.

Alternating current has to be used for high-current argon-arc tungsten-electrode welding, and one of the first problems encountered was partial rectification, a d-c component superimposed on the alternating current. Studies of the arc during a-c welding have shown that the arc has a cleaning action on the weld metal during the half-cycle in which the electrode is positive. With partial rectification, the d-c component is always such as to make the electrode negative; hence the cleaning action of the arc is reduced. Partial rectification also causes a-c meter readings which are lower than the actual current demand on the transformer primary. Unless taken into account, this may lead to overloading of the transformers.

Partial rectification can be balanced out with storage batteries or capacitors in the welding circuit. Laboratory experience has indicated that when welding manually at currents up to 450 amperes, there were no deleterious effects on weld quality when the current was unbalanced, but balanced current appeared to give slightly more stable operating conditions with mechanized welding at higher currents. Because of the danger in overloading transformers, balanced current is preferred in production.

A major necessity in any welding operation is a stable arc. Arc instability in argon-arc welding may be caused by: excessively high current causing melting of the tungsten electrode; too cool an electrode (especially at the start of a weld), or contamination of the electrode by spatter; or failure of the arc to reignite after deionization during reversal of the alternating current. The first two troubles can be corrected readily by adjustments in welding conditions or techniques; the last is remedied by use of high-frequency stabilization, either continuous or intermittent (at the start of welding or when the arc is extinguished during a weld), or high open-circuit voltages. When manually welding with conventional transformers (80–100 volts open circuit), continuous high frequency is desirable, but with specially designed transformers having higher open-circuit voltages, the intermittent high frequency appears adequate.

Laboratory experience with mechanized welding suggested that continuous high frequency enabled a longer stable arc to be maintained. This permitted easier mechanical feeding of the filler wire, and better adaptability to variations in the height of the weld pool. High frequency has the disadvantages of possible radio interference, and of a tendency to cause the arc to jump to the sides of grooved joints in thick plate.

Laboratory experience with various open-circuit voltages indicated that when continuous high frequency was used with currents above approximately 300 amperes, high open-circuit voltages did not improve the arc stability. Production experience, with machines having intermittent high frequency, indicated that a high open-circuit voltage was preferable.

Automatic welding of thick sections would have many advantages over manual welding, but the development of such a process for argon-arc welding has been impeded by the lack of a sufficiently responsive wire-feed-speed control for a-c welding. Use of small-diameter filler wires (under one-eighth inch diameter) may eliminate this difficulty.

Many of the problems encountered in argon-shielded tungsten-arc welding thick aluminum are being overcome by improving presently available equipment. A still greater improvement is made possible by a new process recently developed at the Air Reduction Sales Company laboratories, and at Battelle Memorial Institute. Here the use of an argon-shielded aluminum electrode eliminates many of the problems encountered in argon-arc welding with the tungsten electrodes. Briefly, this process permits the continuous welding of aluminum, automatically or manually, in all positions, using conventional d-c welding machines. Greater deposition rates, and lower argon consumption per unit of deposited weld metal can be achieved with this process than with the tungsten-electrode process.

Equipment and Techniques in Gas-Shielded Arc Welding; *E. H. Roper* (*Air Reduction Sales Company, New York, N. Y.*).

Gas-shielded arc welding has reached in the last decade a state of development that older welding processes have been half a century in attaining. With the more recent improvements this relatively new process is able to perform welding in a manner that we scarcely would dare dream about a few years ago.

From a simple manual holder using a tungsten electrode, a standard d-c arc welding, generator as a power source, and helium as a shielding gas, a means of welding magnesium was developed. Experimenters tackled other metals. Problems arose which were solved by the use of argon gas. Using various combinations of helium or argon, tungsten or carbon electrodes, and d-c straight or reversed polarity, current techniques were developed to handle stainless steels, nickel, monel, inconel, copper, and copper alloys. Mechanization of the process naturally followed with the development of machine and automatic equipment along with the techniques for their application.

Because it is so closely akin to magnesium and presents much the same problems in welding, aluminum was one of the first metals

to come under scrutiny as possibly being weldable by this process. It proved a tougher nut to crack, requiring the use of alternating current which in turn brought problems of arc stabilization, rectification, and so forth, which called for modification in equipment and operation.

Without some means of adding filler metal any welding process is limited seriously. This is taken care of in manual operation to some extent by using a technique similar to that used in oxyacetylene welding. An obvious solution for mechanized work is to feed continuously a wire into the weld pool using a pair of power-driven rolls to replace the hand of the operator. But the large scale deposition of filler metal calls for drawing the arc between a consumable continuously fed electrode and the work piece, as in submerged arc welding. Practical equipment and techniques have been developed for a means of operating a consumable continuously fed electrode in a gaseous shield and the deposition of filler metal in all positions. Both manual and machine equipment are available and the technique has been worked out for the welding of aluminum and other metals.

Thus in a few short years gas-shielded arc welding has attained real stature.

Equipment for Inert-Arc Welding; *A. U. Welch* (*General Electric Company, Holyoke, Mass.*).

Inert-arc welding differs from other types of welding in so many ways that consideration must be given to numerous factors in order to determine the equipment design that will operate in the most economical and convenient manner. Cost of gas is a very important consideration in this process. Design of the equipment, both the power unit and the electrode holder, has a profound influence on the cost of operation. Design of the welder also is determined by considerations of safety to the operator, quality of weld, and avoidance of radio interference. Gas must cover the arc and metal being welded at all times while either the work or electrode is hot in order to avoid faulty welds. Previously used control devices have been found by experience to be inconvenient or unsatisfactory. Starting a weld on aluminum requires special consideration to avoid picking up aluminum on the electrode. With idlematic control the equipment can be designed to permit easy starting, high quality welds, economy in the use of gas, and to keep radio noise to a time so short as to be comparable to the click caused by switching any electric equipment.

Radio Interference Problems in Welding; *C. W. Frick* (*General Electric Company, Schenectady, N. Y.*).

It is desirable that engineers be informed as to the possibility of interference with radio or other communications and how this possibility can be minimized. Some of the effects associated with various types of welding which may cause interference under some conditions are disturbances produced by the operation of contacts, commutators, spark gaps, and so forth, and high frequencies superimposed on the welding circuit to facilitate the welding operation, all of which may react on radio systems. Also there is wave-shape distortion which may react on wire communication.

The factors involved in an interference situation may be divided into three groups: influence, coupling, and susceptiveness. In the case of welding the influence factors include the disturbances and means for controlling them. Coupling factors depend on the location of the welding equipment, for instance those associated with equipment in an industrial plant would differ from those associated with equipment in a machine shop in an airport. Susceptiveness depends on the type of communication service as well as the design of the communication equipment. Closely related to this subject is the nature of the communication service, for instance whether it is used to protect life and property or to furnish entertainment.

Experience with problems of this type over many years has led to the development of coordinative methods. These methods contemplate the control of the three factors in an efficient and economical manner. Procedures that have been followed in other situations suggest what might be done in the case of welding equipment. When radio frequency is used it has been found desirable in some applications to operate on assigned frequency bands. Such operation is provided for in rules adopted by the Federal Communications Commission which also states conditions under which equipment using radio frequency may be operated on other than assigned bands.

In order to understand some of the basic considerations pertaining to radio interference, the disturbance can be treated as a voltage source. In welding the source might be a single frequency as produced by a vacuum tube oscillator, a band of frequencies as produced by spark gas oscillators, or a complex disturbance known as radio noise. The source acts like a generator connected in the apparatus circuit along which the disturbance is carried conductively. Electric and magnetic fields are set up in the vicinity of these circuits. Radio antennas or connecting leads situated in these fields pick up the disturbances and transmit them to the radio equipment. The effect on the radio depends on the relative strengths of the desired signal and the disturbance. Under some conditions the apparatus circuit or some part of it acts like a radio antenna and transmits the disturbance by radiation. Means for minimizing the disturbances include use of the most favorable types of circuits, proper adjustments, and so forth, and also shielding properly applied and to make it effective, as well as the effective placements of grounds. Precautions should be observed in the installation of filters when used.

Recent Advances in Single-Phase Welding; *Ivar W. Johnson* (*General Electric Company, Schenectady, N. Y.*).

The initial application of the current to a spot weld may have a decided effect upon the obtaining of satisfactory welds in production. Where the wave shape is readily controlled, as it may be with capacity-stored energy equipment, it has been demonstrated that the wave shape affects the welding characteristics. It was the purpose of this investigation to study the effect of varying the envelope of the current of a standard 60-cycle spot welder, during the first few cycles of a spot weld. The slope of this envelope, or the rate at which the current rose to welding value, was adjustable in terms of cycles to reach final current.

The spot welding of aluminum and its alloys is one of the most difficult production jobs involving resistance welding. The major portion of this investigation, therefore, was devoted to spot welding of *24ST* aluminum in four thicknesses: 0.025 inch, 0.040 inch, 0.064 inch, and 0.081 inch; *52S* aluminum, 0.062 inch thick, also was welded.

One serious problem encountered when spot-welding aluminum is the relatively short electrode-tip life. Sticking of work to the electrodes, caused by pickup or deposition of aluminum on the electrodes, was used as an indicator of electrode tip life. The study of this aspect included test runs made to determine the number of spot welds that could be made before any evidence of sticking was observed.

The following is a tabulation of the results obtained:

Material Thickness	Number of Spots Welded Before Sticking Occurred: Without "Slope Control"	With "Slope Control"
On 24ST Alclad		
0.025	15	300
0.040	25	825
0.064	41	1,125
0.081	85	1,700*
On 52S Aluminum		
0.062	60	450

* Tests discontinued before sticking occurred.

These data indicate that there may be a decided advantage gained by controlling the "slope" of the first few cycles of current. This advantage may be due to various factors. One possible way to explain what happens is to consider the period of current rise as a period of "electrode seating." The suppressed current is sufficient to soften the metal and permit the electrodes to seat themselves before welding current is applied. By varying the rate of current rise, it is possible to maintain the same current density at the point of contact between the electrode and the work. Inertia and friction in the electrode system also tend to reduce the actual electrode force applied during the formation of the weld nugget. Without the "slope control" there is an abrupt drop in electrode force, but when the "slope control" is used, there is a very gradual decrease in force as the current rises. This discussion may be summarized by stating that the "slope control" permits the maintenance of constant current density and eliminates the abrupt drop in electrode force. Both of these factors have a direct bearing on the temperature developed at the surface of the work.

Sufficient data have been taken to indicate the advantage of increased electrode tip life on production work when using slope control.

Some Practical Comparisons: Single-Phase Versus 3-Phase Converter. *F. L. Brandt, L. S. Wilkins, R. J. Uredenburgh, Jr.* (*Thomson Electric Welder Company, Lynn, Mass.*).

There are several comparisons between single-phase and 3-phase systems in recent

literature and advertisements. The comparisons usually refer to ratios, graphs, or tables showing the electrical demands for various throat depths of resistance welding machines, systems, or for welding of different materials and gauge thicknesses.

The data reported herein are obtained directly by welding the same material in the same machine setup on the same power lines during the same hour of the day and with the same oscillograph wiring on two similar welding machines. The only principal difference is the welding transformer and control. One machine is equipped for single-phase and one for 3-phase operation. All welding is performed on pieces cut from the same metal sheets and the identical welding tips are transferred from one machine to the other to insure the same contour. The welds are cut and etched to observe similar nugget formation. Test coupons are pulled for tensile comparison. Rows of spot welds are made to compare current variation as sheets of magnetic material enter the welding machine throat.

The resulting oscillograph prints are studied and correlated to show current demands and voltage regulation. The expected reduction in current demand is confirmed. The limited power supply lines feel the single-phase demand which is reflected in the voltage drop. The voltage drop on the low-frequency converter equipment is practically negligible. The difference in choking effect of welding current due to magnetic material entering the throat of the welder clearly shows the need for a current compensator on single phase and absence of such need at the low frequency of the converter on three phase.

Application of Metallic Rectifiers to Resistance Welding; *R. H. Blair* (*Taylor-Winfield Corporation, Warren, Ohio*).

In designing a new type welder to meet the needs of industry better, experience gained from former designs indicates that certain features should be incorporated. Among these features the foremost is a low 3-phase balanced demand to relieve overloaded power lines. The machine should be flexible for use on ferrous and nonferrous materials alike and should be low in cost to help those machine users who cannot afford a number of specialized high priced machines. Looking at the problem from the angle of the maintenance man, the machine should be rugged and simplified to reduce breakdowns and specialized servicing. More rigorous welding specifications indicate that the machine should have good welding characteristics either as a seam welder of aluminum or a heavy steel spot welder.

In investigating the characteristics of the magnesium-copper sulphide rectifier cell, it was found that this cell offered some very natural and favorable characteristics for d-c resistance welding. First, this cell can take very high current densities on duty cycles typical of a resistance welder. The inverse resistance characteristic of the cell offers some current regulation benefits. By proper design the metallic-type rectifier is made to serve three functions: rectification; stabilize the circuit to some degree; and, at the same time, offer a degree of self-heat regulating effect when the load resistance suffers a change.

Conduction cooling of the rectifiers has been developed in place of the usual air blast and the rectifier units have designed into standardized and compact units sufficiently small to fit into standard welder frames. Primary current control is accomplished by two ignitron contactors using size *A* or *B* ignitron tubes and controls are relatively simple.

Three-phase demands usually fall between 20 and 50 per cent of the single-phase 60-cycle demand on equivalent machines. Power packs in multiple power pack machines can be operated independently so that on the two power pack machines 72 steps of heat regulation are available with full conduction on each step.

The relatively low rate of rise of d-c weld current, high ratio of rms to peak current, and self-regulation of the weld current provide welding characteristics that are superior to 60-cycle welding in nearly all instances.

Installation for Low Maintenance; *J. W. Quinn* (*Delco Products Division, General Motors Corporation, Dayton, Ohio*).

Installation for low maintenance requires that thought be given to maintenance at the time equipment and facilities are to be procured.

Adequate electric power, compressed air, water, sewer capacity, and plant layout have a definite effect on maintenance cost and each must be considered for the specific case. A separate power supply for single-phase loads will improve plant operations. Air, water, and sewage problems increase in complexity in direct ratio with the plant layout.

When procuring a piece of equipment it is necessary to insist that several features be included in the original requests for quotations. The type of timing controls, air valves, pressure switches, control relays, time delays, push buttons, disconnect switches, size of seam welding wheels, spot welding tips and holders, and alloys to be used should be stated if any preference exists. An aid to the maintenance departments is a separate control panel located adjacent to the machine with designed interconnection to facilitate the rearrangements which occur due to schedule changes and model changes. Accessibility of perishable items should be stressed. There has been a tendency in the past five years to streamline machines, but this usually is accomplished by sacrificing of accessibility. Location of motors also should be covered as this is a definite maintenance cost whenever replacement occurs.

During and since the war, additional electronic control equipment has been added to the facilities of the Delco Products Division which brought about another maintenance problem. The majority of the electricians were not adequately trained to maintain these more complicated systems. To improve this condition a general and specialized course was given to acquaint the men with the most common failures and their remedies. All electricians were included in the general course and approximately one-half of them in the specialized course.

Preventive and Corrective Maintenance of Welding Equipment; *Charles H. Davis, Jr.* (*The Budd Company, Philadelphia, Pa.*).

The Red Lion plant of The Budd Company manufactures stainless steel railway passenger cars and truck trailers, and as the products would indicate, it is primarily a sheet metal fabricating plant. The Budd Company has pioneered the spot-welding of stainless steel using the Shotweld system, which involves the use of full synchronous timers and I^2T recorders.

At the present time, there are approximately 350 portable welding setups, 20 press-type welders, and several automatic welders in operation. The maintenance of this equipment can be divided into two classes: electrical or electronic maintenance, and mechanical maintenance. The welding maintenance department is responsible for the maintenance of all welding equipment, exclusive of arc-welding machines, which are serviced by the plant electrical department.

Preventive maintenance as practiced at this plant has been dictated, in a large part, by previous experience with the equipment involved. For the most part, this consists of mechanical service in the form of regular and routine lubrication of moving parts, either through air line lubricators or grease fittings on the machines. On certain 3-phase machines used for spot-welding of aluminum, this has been extended to mechanical cleaning of the secondary circuit to eliminate high-resistance joints which cause excessive loss of welding current.

Due to past experience with the synchronous timer, maintenance of this equipment is primarily corrective. There are certain items such as the periodical cleaning of water strainers which could be classed as preventive maintenance, but the major policy on this equipment is one of corrective maintenance.

Use of Instruments in Maintenance; *Ralph H. Pelton* (*Precision Welder and Machine Company, Cincinnati, Ohio*).

The need for basic modern test instruments is very important in industry if efficient operation of welding equipment is to be expected. Too many companies still expect or hope to keep highly electrified equipment operating without substantial down time with the use of bell ringers, test light, and so forth. This is neither fair to the maintenance department nor to the factory. It has been proved many times that any average electrician who is interested can be readjusted quickly to maintenance of electronic controls, if given a few basic instruments adaptable for the work involved.

The first and most important on the list for general trouble shooting is the modern combination meter. The cost is so relatively low that there should be no excuse for not having at least one available at all times. It is necessary to understand all the functions, limitations, and so forth, of this type of instrument to get the most help from it. The combination meter covers all ranges of voltage, alternating and direct, nearly all ranges of resistance, and small ranges of direct current. With its aid a good many component parts can be checked by several methods.

If synchronous or all electronic controls are to be maintained, it is essential that a cathode-ray oscilloscope be available for trouble-shooting when trouble cannot be located by simpler methods. An oscilloscope may indicate trouble that cannot be diagnosed positively or quickly with meters or visual observation. A few of the observations that may be made are heat control, heat balance, short timing checks, consistency test, phase angle relations, and wave forms.

The cycle counter is an excellent instrument for the checking and setting of weld time calibrations. This is particularly true when using short weld times for high-speed operation. Some timers may operate with a shorter weld time than for which they originally were designed. As the percentage of accuracy or consistency is invariably greater on shorter weld times, it is important that the timers do not go below three or four cycles (0.05 to 0.066 second). To the eye, this is a very short interval. It is recommended that the cycle counter be of the recording type (record on paper strip).

The next instructions on the list usually are purchased in a group. They are a current transformer of the split-core type and a portable high-accuracy a-c voltmeter and ammeter with stop pointer back stop cases. The stop pointers are very essential when being used around resistance welders, because of the short times during which they may be available to read voltage or current. The split-core type of current transformer is the only practical current transformer for service work.

There are several methods of reading the current flowing in the secondary of resistance welders. As the current is always in thousands of amperes, direct readings cannot be made. The ideal place to measure welding current is in the secondary circuit of the welder. However, this method is used very seldom except by engineers because of the mechanical difficulties involved in setting up to make such test. The simplest way to estimate the welding current is to read the primary current during a weld with the aid of the current transformer and ammeter. This reading then is multiplied by the turn ratio of the welding transformer to obtain the secondary current (weld current). There are several things to watch when using this method which will give more consistent and accurate results if followed.

As watt meters are used only if it is necessary to know the power factor of a welder, they usually are used only for engineering data, and are not required for service. There may be one possible exception. A series capacitor installation may be tuned for near unit power factor with the use of watt meter and current transformer.

Magnetic oscillographs often are used to advantage for power factor reading and checking for unusual conditions. The first cost of this type of equipment often makes its use prohibitive. There have been instances, however, where its use has been paid for on one job.

Very few people are using industrial tube testers; the main reason is the initial high cost of satisfactory tube testers for the type of testing as compared to actual need.

There are available on the market special capacitor testers which cover about every test required of capacitors, resistance measurements, and, to a limited extent, insulation test under direct voltage.

The successful use of instruments in maintenance requires, first, a satisfactory understanding of all instruments on hand, second, a basic workable understanding of the equipment under maintenance, and third, a practical understanding of when to use instruments to advantage. They then may be put to work, saving time and money whenever trouble occurs which cannot be located by visual observation.

Training Men to Maintain Welders and Controls; *Bert J. Gelmine (Ford Motor Company, Dearborn, Mich.).*

For many years the training department of the Ford Motor Company has been training apprentices and other personnel in industrial electricity, a course which also includes welder controls.

Within the last two years a large percentage of the controls for welders in this company, including its branch plants, has been replaced with electronic types. This equipment is to be installed and maintained by electricians, many of whom are very competent in general maintenance. It became the problem of the training department to enlarge their background to enable them efficiently to service this newer and unfamiliar electronic equipment with instruments that were also unfamiliar. Hence, a special training program was established for key men, who are expected to relay this information to the other electricians. These men attended a 40-hour program during working hours over a period of ten weeks.

The training method developed was based on the fact that efficient maintenance can be accomplished only by men with thorough knowledge of the equipment and also a good knowledge of trouble shooting techniques. Lectures, demonstrations, and illustrations were used to present the material. Explanatory sheets, instruction bulletins (obtained from manufacturers), and work sheets were issued for home study.

At the beginning of the period, questions previously assigned were considered. These often brought about very beneficial discussions. The fact that the men were very experienced, brought to light common occurring faults and how to overcome them.

For demonstrations, panels were made, which were wired to dummy loads and actual welders. They were used to show how welding controllers actually function and how to make tests. All of these panels operate. With them it is possible to cover operating characteristics of electron tubes, basic welding control circuits, and type *3B* welding controllers.

Actual welder controllers also were used.

For illustrations, use was made of cutaways, visual aids, and charts.

The following material was covered:

1. Components of resistance welders and controls.
2. Review of units used in electronic circuits.
3. Basic welder circuits.
4. Westinghouse and General Electric type *3B* spot welders.
5. Weltronic spot welders.
6. Multielectrode spot welders.

It is surprising how experienced electricians learn to detect faults quickly by merely observing the operation of the welder controller, making a few tests with a test coil, making visual inspection of some of the parts, and questioning the welder operator. As an example, an electrician looking at the tubes and relays of a General Electric type *3B* welder can tell invariably where the fault lies. He knows how the tubes should flicker and how the relays should open and close. Whenever the action does not occur true to form, this suggests where the fault lies. Because this method of trouble-shooting is so effective, it was stressed highly throughout the course.

Some of the tests and additional observations performed are as follows: Check line voltage, test fuse in igniter circuit, look into top of ignitron tubes to see if they both fire, look at other tubes to see if the flicker is of correct duration and intensity, check flow switches to see if their contacts have opened, inspect the rectifiers for discoloration, feel temperature of resistors and electrolytic capacitors. If the fault occurs in the replaceable section of the controller, this section is replaced, the faulty section being taken to the repair shop for repair. This is done to reduce work stoppage to a minimum.

Where the fault cannot be isolated by the method just explained or in the case of special or more complicated welder controls, the electrician makes use of electrode pressure gauges, cycle recorders, multitesters, oscilloscopes, and so forth.

Training Men to Maintain Welders and Controls; *L. M. Skidmore (General Motors Institute, Flint, Mich.).*

The following steps were taken by Fisher Body division in co-operation with General Motors Institute, central training agency for the General Motors Corporation, in meeting a technical operating problem through training.

THE PROBLEM—STEP I

The trend in automotive body manufacturing of placing resistance welding machines in the production line rather than the sub-

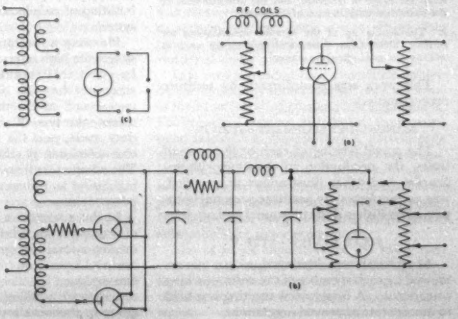


Figure 1. Wiring of panel used to demonstrate characteristics of tubes

assembly stations makes it increasingly important that each welding machine be kept operating at its highest degree of effectiveness during the entire shift. It has become more and more difficult to accomplish this as welding machines increase in complexity and as personnel, new to welder maintenance work, is placed on the job.

Therefore, the management of Fisher Body division approached General Motors Institute with this problem: Accurate analysis of any trouble and the correction of the trouble in a very minimum of time.

PLANNING TO MEET THE PROBLEM—STEP II

To insure that all phases concerned with the problem be represented and viewed in their proper perspective, a group of Fisher Body personnel, representing production, engineering, training, and top management met with General Motors Institute personnel to

1. Analyze the problem.
2. Consider ways and means of meeting the problem.

During the analysis of the problem it became apparent that a resistance welding machine maintenance manual would be needed that dealt with specific types of machines and their related controls currently in use. To be effective, this manual would have to be kept up to date by deletion of obsolete information and the addition of new information as rapidly as changes are made in the equipment used. To facilitate these changes it was planned to number each manual and keep a record of the name of each individual receiving one. In this way alterations can be supplied immediately to all manual holders. This planning group further determined that the manual be so constructed that maintenance fundamentals in five areas be included: welding, mechanical, pneumatic, hydraulics, and electrical.

This group established a working committee of individuals from the various plants in Fisher Body division well qualified in the five areas to be covered by the manual. Their responsibility was to set detail specifications for content of each section.

MANUAL DESIGN—STEP III

The actual design of the manual content was completed in a series of meetings held by this working committee.

The approach to setting the content specifications was

1. A careful analysis of each of the five areas to determine the range of coverage, and the establishment of the individual units in each of the areas.
2. The setting up of the detailed specifications for content, illustrations, form, and style to be used in writing and producing the manual.

This work was co-ordinated by institute representatives.

MANUAL DEVELOPMENT—STEP IV

The actual writing of each of the manual units, the production of drawings, photographs, and other illustrations as specified, was accomplished by Institute personnel supported by Fisher Body personnel and services.

FINAL REVIEW—STEP V

As each unit was developed, a copy was reviewed by each member of the entire working committee. A final review meeting was held to incorporate approved suggestions.

FINAL PRODUCTION—STEP VI

The final production of the manual was the responsibility of the institute.

ASSURING THE USE OF THE WELDING MACHINE MAINTENANCE MANUAL AS A MAINTENANCE TOOL—STEP VII

The making available of this tool for the effective maintenance of specific welding machines and controls provides no assurance that it would be used or that its objectives would be obtained. Therefore, as progress was made in the development of the manual, plans were formulated to insure its effective use.

These plans provided that each maintenance man in the various Fisher Body plants would be given a course of instruction based on the information contained in each unit of the manual. The instruction would be given in an organized series of classes and conducted by technically qualified maintenance supervision. It thus became necessary to prepare maintenance supervision for the job of training others.

TRAINING THE TRAINER—STEP VIII

Instructors guides for each section of the manual were prepared by institute personnel.

Fisher Body plants selected certain of their technically qualified supervisors who were sent to the institute for 40 hours of intensive training.

This training was directed toward three objectives:

1. To familiarize the trainer with the organization of the content of the material to be presented to the trainee.
2. To familiarize the trainer with the use of the instructors guides, the manual, and other training aids.
3. To aid the trainer to develop skills and techniques of training others.

Upon completion of this period of training, the trainers returned to their respective plants, organized their maintenance personnel into groups, and started the formal training on specific application of mechanical, hydraulic, pneumatic, and electrical principles to the resistance welding of sheet steel.

Power Supply Problems as Viewed by the User; *Thomas O. Morgan (Buick Motor Division, General Motors Corporation, Flint, Mich.).*

The automotive industry learned about the economical advantages of resistance welding while emerging from the depression years of 1932–33, but there was a lapse of seven years before sufficient information was compiled so that quality parts could be made for the building of an adequate welding distribution system.

Planning a resistance welding distribution system for high intermittent load duty should be given real consideration. Many factors enter into the exact design for good performance—such as the number of welding machines, the type of welding, size of welders, duty cycle, and the physical and electrical characteristics of the welding machinery. The adequate system must have good voltage regulation and must not interfere with other power systems.

In the automotive plants, the major class of welding is the fabrication of steel parts requiring a total voltage regulation from 10 per cent to 15 per cent. Invariably a power system designed for adequate voltage regulation to resistance welding loads also will be adequate in thermo kilovolt-ampere rating. As an illustration, the Buick plant has about 40,000 connected kilovolt-amperes in welder machinery served by 9,900 kva of power transformer rating, and the average kilovolt-ampere heat value is only 1,200 kva.

The following will give an idea of the proportions of an automotive welding supply system. The 60,000-kva utility bus has, in this instance, an almost unlimited energy supply, thus for all practical purpose any computations are usually based on a fairly steady reference voltage on owner's 4,800-volt bus. Surges appearing on this distribution bus are ironed out by a 10,000-reactive-kilovolt-ampere synchronous machine floating on this bus. The primary welding feeder is a direct and independent feeder direct to the respective factory load centers. No other power is attached unless under rare state of emergency.

The secondary shop distribution system is streamlined to a minimum number of standardized parts.

The transformer is an outdoor-type 300-kva single-phase oil-immersed self-cooled transformer with coils especially braced to withstand high currents, and having extremely low impedance of 1.7 per cent. Three such transformers are normally used on each substation bus, although ultimate arrangements usually are made for five units.

The main circuit breakers are placed close to the transformer bus in a drawout cubical assembly. Their adjustable instantaneous trip coils are set to ride just above normal load conditions.

The main bus is a 2,000-ampere low-reactance bus with arrangements for branch service connections ten feet apart.

The service tap is made by removing a bolted plate and installing a tap box and assembly to receive a 750,000-circular mil 2 conductor concentric cable.

This concentric cable constitutes the branch circuit and feeds a distribution junction box ordinarily spaced less than 25 feet from the bus tap, although in some instances it may run much farther since its a-c resistance is comparatively low.

The distribution junction box has a capacity for ten small machines or five larger machines. This box is constructed with strongly supported busses and good insulating materials.

The machine service drop to the machine service switch is rather short, using conduit with taped cables. Machines of 600 kva, or above, in rating may be fed directly from the main bus with 750,000-circular mil concentric cable eliminating the junction box.

These distribution systems prove very flexible; they can be extended, there is no problem of alignment, all parts assemble easily, and there is almost a 100 per cent salvage value in case of reconversion.

Reliability is attained by the purchase of reliable manufactured parts with correct installation.

All substations are placed on the roof directly above the load centers. The bus risers from these stations to the shop areas are installed high out of reach of any shop activities. Hatches and handling equipment in the substations facilitate easy replacement of equipment.

Safety, in systems of this type, comes as a result of specialized training, continuous inspection of equipment, and safe working conditions.

Many good features used in welding distribution are applicable to ordinary factory power systems. Their primaries usually are terminated at the same place with provisions for emergency tie, and their system of secondary busses similarly arranged.

Dummy Loads Applied to Large Industrial Welders to Reduce Voltage Fluctuations; *A. W. Brown, S. E. Johnson (Illinois Northern Utilities Company, Dixon, Ill.).*

During the recent war an industrial plant contracted to weld aluminum watercans with six large single-phase seam welders which would have caused objectionable voltage fluctuation on the power supply system. Satisfactory welds required the use of electronic timing with the current turned on and off in a recurring sequence of two or three cycles on and five or six cycles off depending on thickness of aluminum sheets used. This resulted in the most objectionable frequency of fluctuation and only about 0.4 per cent voltage fluctuation affecting other customers could be permitted.

The welder manufacturer lacked definite information in advance of constructing the welders as to their actual demand. The industrial plant was located remote from the power source and construction of a transmission line of adequate capacity was not feasible in the time available. The usual methods of limiting fluctuation such as lengthening the welding time, interlocking the welders to prevent simultaneous operation, and equipping the welders with series capacitors would not have resulted in sufficient reduction in instantaneous demand and consequent light flicker. The use of a motor-generator set to spread the single-phase load of each welder over all three phases and to utilize the flywheel effect of the induction motor drive would have been applicable except for high cost, and long delivery on rotating machinery of this type during World War II.

The solution selected consisted of electronically interlocking each single-phase welder with a dummy load to fill in the period of no load between welds and of suitable magnitude to keep the voltage variation within allowable limits. The welders were purchased equipped with series capacitors which were planned to reduce the size of supply facilities required and to correct the power factor to approximately 95 per cent lagging. Dummy loads could be smaller than welder loads so long as difference between the demands of the two types of loads did not result in more than 0.4 per cent voltage variation. It was recognized that the voltage variation on the phases other than the one to which a particular single-phase welder was connected had to be considered in the design of the dummy load.

Each of the resistance-type dummy loads selected was equipped with electronic timer and as first applied was interconnected with one welder so that the ballast load was on for the five or six cycle period between stitch welds and also for the longer periods for changing the work. Most of the heat from the resistance ballast loads was dissipated in heating the surrounding air. However, some of the ballast consisted of immersion heaters used in heating fluids for other processes. The actual demand during satisfactory aluminum seam welding operations proved to be approximately 58 per cent greater than had been anticipated and the series capacitor equipped welders operated at 87 per cent rather than 95 per cent power factor.

The original 140 kva of dummy load per welder as selected consequently was inadequate to limit voltage fluctuation to a satisfactory value. The electronic control engineers devised a method of increasing the effectiveness of the dummy loads by interlocking two of the welders and combining two dummy loads in parallel on one phase with timing so arranged that one welder would be on for two or three cycles, then another for an equal period, and then the combined 280 kva of dummy load would be on for the remaining "off" period of four or two cycles between welds. The frequency of fluctuation then was cut in half and the quantity of flicker considerably reduced, both because of greater effectiveness of ballast load and because two welders on one control could not be on simultaneously. Another advantage to the welder user was a considerable reduction in kilowatt-hour consumption of ballast load since one welder acted as a ballast for another on the same phase for a portion of the time formerly taken up by the dummy load.

The following conclusions may be drawn:

1. A dummy load switched by electronic control can be used successfully to limit voltage variation resulting from the operation of seam welders or other similar loads of known fixed quantity and power factor.

2. The kilovolt-ampere demand of the welder should be reduced and the power factor improved to approximately 90 per cent by the application of series capacitors in the welder circuit.

3. Dummy loads appear to have considerable promise in supplying welder demands in excess of the capacity of the supply system, particularly if the power consumed in these ballast loads can be utilized in heating of liquids or in other industrial heating processes.

Distribution Systems for Resistance Welders; *W. K. Boice (General Electric Company, Schenectady, N. Y.).*

A distribution system well suited for supplying resistance welders may differ in several respects from a system designed primarily for other types of load. This is true principally because of the intermittent nature of resistance welder input currents.

In order to design a system which will meet the requirements of resistance welders with maximum economy, and without undue disturbance to other loads, certain preliminary data are needed. For example, the designer must know the characteristics of the welder load, including the number and locations of machines, their maximum kilovolt-ampere demands, power factors, duty cycles, and whether the machines are single-phase or 3-phase types. If alternative types of machines are to be considered, he must have such information about each of them. For welders which draw appreciable amounts of harmonic currents, the fundamental (60-cycle) components of their currents should be known, as well as the power factors of these components (vector power factors of the machines), because these components largely determine the voltage drop. The system designer should know the maximum voltage drop allowed for a satisfactory weld, and the acceptable percentage of welds with greater drop, caused by occasional welding by several machines at the same time. The amount and nature of loads other than welders should be known also, so that a system for combined loads may be considered. The amount of lighting load is important if flicker must be avoided.

The impedance of the supply system furnishing power to the industrial plant must be known, because the voltage drop in this supply system adds to any drop in the distribution system.

By the use of certain curves, it is possible to determine the maximum allowable system impedance to meet the requirements of one welder, a group of welders, or a lighting load combined with one or more welders. Such curves are based on the probabilities of occurrence of drops exceeding any specified amount. Curves also may show the required rms kilovolt-ampere capacity to supply one or more welders without overheating the transformer or other components of the distribution system.

If the impedance of a substation is excessive, a transformer of larger kilovolt-ampere rating may be used. Usually the bank rating is determined by the limiting impedance rather than conductor heating. Because simultaneous operation of all welders in a group is unlikely, it is usually impractical and unnecessary to design for this condition. As the number of welders per substation increases, the required transformer capacity increases relatively slowly, so that the transformer cost per welder decreases. As more welders are added to a bank, however, the cost per welder of cable or bus to distribute the power increases, and the cost of switchgear rises with substation rating. Hence there is an optimum number of welders per group for any particular set of requirements. This optimum number is affected principally by the distance between welders, the severity of voltage drop limitations, being smaller for large welder spacings, and larger for more severe voltage drop requirements.

Combination of motor or heating loads with welders greatly will reduce system costs chargeable to welders. Power loads and welder loads seldom interfere with one another, and power loads can make use of the excess rms current capacity of welding substations.

Combination of lighting and welding loads is economically attractive whenever the increased transformer capacity required to avoid flicker does not cost more than a separate lighting supply. When more than one substation is used in a load area, lighting and power may be supplied from one substation and welding and power from the other.

Cost data may be used to estimate the system cost savings obtainable by reducing welder demands. When these savings are compared to the cost of equipment for reducing the demand, one can determine whether it is more economical to use special welders to reduce welding loads, or to design the power system adequately to serve conventional single-phase welders.

It is recommended that concentric cables be used to supply individual welders, because of their low installed cost and low impedance. For groups of welders, distribution from overhead busways is recommended, particularly where flexibility for machine rearrangement is desirable. In general, 3-phase substations are preferable to permit combination of 3-phase power loads with the welding load. For individual large welders, single-phase substations are more economical.

Use of series capacitors at the substation primary has been found to be advantageous in a number of cases involving groups of welders with severe voltage drop requirements.

When more than one transformer bank is needed for the entire load near the welding area, double substations with normally open secondary tie circuit breakers offer the added reliability of a secondary selective system at moderate increased cost. When voltage drop limits already necessitate high short-circuit current levels and large total connected transformer capacity, the superior reliability of a secondary network may be obtainable without great additional cost.

The proved economic advantage of load center distribution with substations indoors near the load are just as significant for resistance welding loads as for general plant use.

Utility Problems in Supplying Power for Resistance Welding; *H. B. Wood (Duquesne Light Company, Pittsburgh, Pa.).*

For the past 15 years or so, the application of resistance welding has progressed greatly, increasing correspondingly the number of welder services on the utility system. With the increased use of this type of welding during the war, further demand for welder services undoubtedly will accelerate during the coming years. Many schemes are used to connect welder loads to provide adequate voltage without undue annoyance to other customers. When adequate data are available concerning the welder and utility system, service usually can be provided at no great cost to satisfy the foregoing conditions.

Three major problems confront the utility engineer in serving welding loads. They are flicker to other customers served from the same distribution system, adequate voltage at the welder terminals, and low revenue at high investment cost from fluctuating loads. Certain limitations on the amount of fluctuation at various frequencies have been established beyond which flicker to lights would be objectionable, the most critical frequency being around six fluctuations per second. The amount of noticeable or objectionable voltage drop may be reduced and voltage at the welder may be improved by various schemes for reducing the system impedance as viewed at the customer's installation. The repayment of investment cost to the utility for special installations to serve welders is afforded in a surcharge.

It should be emphasized that the limitations in the amount of fluctuation and frequency of fluctuation, or addition of a surcharge, are not fashioned as penalties for connecting welders to the utility system, but these limitations and surcharges are established practice applying to any form of fluctuating load.

The system impedance to the secondary of the distribution transformer on the Duquesne Light Company's 4-kv system may vary between approximately 1.5 ohms and 17 ohms. For other voltages higher than 4 kv, the system impedance overlaps somewhat but decreases to lower values than those for the 4-kv system. Since the voltage drop caused by a specific welder load is its load current multiplied by the system impedance, it is quite possible that, depending on the location on the system, the welder load may be too great to keep voltage flickers and terminal voltage within established limits.

For those cases where flicker is too great or voltage inadequate, many schemes may be used to bring these conditions within limits, such as to replace a 2,300/230-volt transformer with a 4,000/230-volt transformer with corresponding reconnection, connect welder to a 3-phase star-delta bank, replace primary circuit conductors, install a separate feed, install series capacitors in the primary feed, install a translator, or other similar plans.

Most of the utility operating problems involved in the operation of the welder may be solved in advance of trouble provided adequate welder data and system impedance data are available. For this reason, the Duquesne Light Company requests the customer to fill in a "welder data sheet" when requesting service. He supplies the utility with all pertinent name plate data, including maximum currents that the welder can draw even though this may not be needed in the proposed demand of the welder, number of welds per minute, and expected voltage and current at the proposed operating cycle. Other variations in data also are requested on the sheet depending upon the type of welder it is proposed to serve. Using these data and system impedance data, the utility engineer is able to make calculations using various types of connections and thus determine the cheapest method connection which will provide adequate voltage and minimize flicker to other customers.

All of the foregoing discussion of the utility problems points out several major facts. Co-operation between the manufacturer of resistance welders, the user of the welders, and the utility is of utmost importance in providing an adequate power supply for resistance welders. The customer should consult with his utility before purchasing a welder so that no welder of such size or in such location will require a service of prohibitive cost.

Welding Calculations—Effect of Conductor Configuration in Overhead Lines; *H. W. Tietze (Public Service Electric and Gas Company, Newark, N. J.).*

Most electrical calculations involving open-wire construction on crossarms assume triangular spacing of conductors and utilize conductor constants based on the equivalent spacing. If applied to computations of voltage fluctuation caused by single-phase resistance welders on 3-phase supply systems, the equivalent spacing method will lead to large errors. The solution lies in the application of the general formulas expressing the induced voltage effect in any conductor of any line because of its own current as well as to that of the other conductors of the same circuit.

Economical Service for Resistance Welders; *E. F. Dissmeye (The Commonwealth and Southern Corporation, Jackson, Mich.).*

The survival of our economic system is dependent upon an increasingly higher standard of living which requires continual improvement in production methods. Most new production methods are becoming increasingly dependent upon the use of electric power. Resistance-type welding is one of the more important methods being used in the accelerated and economical production of goods. The cost of serving such loads is predominately that of investment in utility plant. The equitable investment of available capital in electricity supply systems to serve welding equipment along with other types of loads therefore requires the proper application of welders and the co-ordination of their load characteristics with others served by the power supply system. The maximum of benefits can be obtained only by the co-operative effort of the welder user and the utility supplying the electrical service.

Where the resistance welding load is small compared to other motor and lighting loads, the user may be able to apply and install resistance welding equipment without seriously affecting the investment required by the power supply company. It generally is agreed, however, that in some instances the revenue received under usual power rates from resistance welders alone will not justify the expenditures required to isolate them properly from other loads so that they can be supplied without disturbing the service of other customers. Decentralization of industry, together with the installation of fluctuating loads in remote areas, presents a particularly troublesome problem.

As a general rule the user should contact the power supply company prior to the purchase of resistance welding equipment. Certain pertinent data regarding the proposed welder installation will be required by the utility engineers who then will be able to inform the user regarding power supply availability and limitations. Also in the case of smaller users the power sales engineers may be of considerable help in not only the application of the welding equipment, but also in the selection of a suitable distribution system for the plant.

The utility should be provided with a complete description of the proposed welder including the type of machine, its kilovolt-ampere rating, primary voltage and maximum open circuit secondary voltage ratings, together with the available taps. The maximum secondary current and power factor also are needed so that the effect of the maximum welder load on the service of other customers can be determined. In many instances a welder may require different inputs for various portions of a welding operation or it may be used for more than one type of weld. In such cases a description of each welding operation should be provided, including the kilovolt-ampere and kilowatt inputs of the welder at rated voltage. Information relative to the length of time of the weld, together with a description of the type of switching equipment to be used, is essential if the utility engineer is to determine the facilities required to supply the load.

In applying the welder the user should select a machine having the smallest kilovolt-ampere input compatible with the required speed of production and quality of weld. In general, properly applied welding equipment results in a minimum investment in machines and in the user's plant distribution system.

Customers should not overlook the possibility of using stored energy and 3-phase-type welders. In many cases one of this type of welder or the use of series capacitors will provide an economical solution for installations where voltage fluctuations would be excessive if the conventional single-phase-type machine were installed. Voltage fluctuations within the customer's own plant may be just as important as those which disturb the service of other customers.

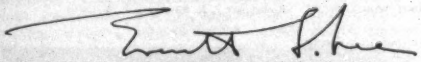
The principles outlined have been applied successfully by many users and utilities and have resulted in a number of satisfactory and economical installations.

INSTITUTE ACTIVITIES

The Electrical Engineer and His Profession

The Board of Examiners—The Committee on Transfers

—*A Message From the President*



I once heard an engineer say, "Oh, anyone can get into the AIEE." That was a thoughtless statement; neither is it true.

The electrical engineers in their AIEE have defined the electrical engineering profession by their membership requirements as embodied in the constitution of our Institute. These recognize the two great fundamentals of our profession: the active participation in the electrical and scientific work of our land; the active participation in the teaching of electrical engineering and electrical science in the engineering schools of recognized standing in our land. On these two fundamentals the electrical engineering profession stands: electrical engineering and scientific training; electrical engineering and scientific achievement.

Our Institute recognizes progression of each electrical engineer through his electrical engineering and scientific life from his eager student days of engineering youth throughout those days of his electrical engineering service well rendered to his associates and to his fellow men. As a student in an engineering school of recognition he finds there has been made available to him the opportunity to enroll in our Institute as a Student Member, and as he applies for this opportunity through his own individual action he begins at the very beginning to recognize the principle of the individual asking of those who have gone before him the privilege of telling of his attainments that he may become associated with them appropriately. Each applicant for enrollment as a Student Member shall be endorsed by a member of our Institute. The application shall be passed upon by the board of examiners, and submitted to the board of directors for action.

The corporate membership of our Institute consists of Associates, Members, Fellows, and Honorary Members. The constitutional requirements for each grade recognize progression through electrical engineering life as measured by individual attainments. Any person may apply for admission; any associate may apply for transfer to Member; a Member may apply for transfer to Fellow upon proposal of five Fellows. Final action is by the board of directors, but the actual scrutiny and findings for recommendation is by the board of examiners.

It is in the board of examiners that the responsibility is vested by the constitution of our Institute for considering the qualifications of applicants for election and for transfer and for reporting its findings to the board of directors for action. All of the members of the board of examiners are Fellows of our Institute. It is to these members of our Institute we look that the grades of our members are appropriate to their attainments as stated at the time. We owe much to these loyal members who give freely of their time that assurance will be positive that the qualifications of our member grades are upheld throughout impartially and with wisdom and understanding. The outstanding devotion to this duty on the part of the members of the board of examiners throughout the years and at present gives to all who ask and seek and wonder the assurance of standards maintained. And to those who give it no thought, it goes on just the same, year in and year out, to the strength of our Institute.

Everett S. Lee

In this great country of ours where men see in each other their character, their personality, and their abilities, the question of grades is not generally considered of great consequence. And yet at times it becomes of paramount importance to the individual. Thus it becomes a substantial part of our Institute life, always there for the foundation on which we stand; always there for the individual need at specific moment. To each member we ask that he give consideration to his own individual position that he is appropriately located.

Our committee on transfers has performed and is performing an outstanding service in bringing to the attention of each member his opportunities for appropriate grade. I ask recognition of the Section transfer committees in this endeavor as they live with the Section membership to effect satisfying results in this regard.

Thus, by the member qualifications which the members of our Institute themselves have written into our constitution, encouraged by our membership and transfer committees, interpreted by our board of examiners, and finally by action of our board of directors, is the electrical engineering profession defined. And the contributions of the members in their everyday living to advance electrical engineering and electrical science for the benefit of their fellow men is the basis of it all. May each member of our Institute continually keep prominently within him, the knowledge that his life is a life of service to his fellow men.

Michigan Section Is Host to AIEE Conference on Electric Welding

Some 436 persons, including representatives of manufacturers and users of welding equipment, as well as utility engineers, attended the AIEE conference on electric welding held in the auditorium of the Rackham Memorial Building of the Engineering Society of Detroit, December 6–8, 1948. This was the fourth of the conference-type meetings to be held in 1948.

Sponsored by the AIEE electric welding committee, the purpose of the conference was to provide an opportunity for an exchange of ideas among persons primarily interested in arc and resistance welding. The program covered topics of interest to users, equipment builders, and utilities. The conference was sponsored by the AIEE electric welding committee, in co-operation with the Michigan Section of AIEE, the Detroit section of the American Welding Society, and the Industrial Electrical Engineers' Society of Detroit.

The conference was opened by J. R. North, an AIEE director, who welcomed the members and the guests present. Additional introductory remarks were offered by E. H. Vedder, chairman of the electric welding committee and general chairman of the conference. He pointed out the large amounts of power used in electric welding and stressed the problem common to the user, manufacturer, and utility companies.

Six sessions covering various aspects of welding and allied topics were featured at the conference. R. C. McMaster, Battelle Memorial Institute, Columbus, Ohio, presided over the first session which dealt with the fundamentals of arc welding. Inert atmosphere arc welding was the topic of the second session which was presided over by E. F. Steinert, Westinghouse Electric Corporation, Buffalo, N. Y. The third session, on resistance welding, featured a round-table discussion on 3-phase welding, and was led by C. E. Smith, Taylor Winfield Corporation, Warren, Ohio. Maintenance of resistance welding equipment was discussed during the fourth session which took place on Tuesday evening, December 7, 1948. This session, presided over by G. M. Chute, General Electric Company, Schenectady, N. Y., was open to the public without registration fee, and drew a large attendance. Two papers on training men to maintain welders and controls were of especial interest to plant personnel. Another phase of resistance welding, plant distribution systems, was the subject of the fifth session led by C. M. Rhoades, Jr., General Electric Company, Schenectady. The final session was on providing power for resistance welding loads and was presided over by C. N. Clark, Duquesne Light Company, Pittsburgh, Pa.

The papers and discussions presented at the conference are to be published in a consolidated pamphlet form and will be announced, when available, in *ELECTRICAL ENGINEERING*. Copies may be ordered in advance at $3.50 each from R. S. Gardner, AIEE Headquarters, 33 West 39th Street, New York 18, N. Y. Brief digests of most of the papers appear herein (*pages 163–70*).

An interesting feature of the conference was the inspection trip to the Ford Motor Company River Rouge plant which drew a large attendance. In addition to seeing electric welding methods and equipment, visitors were afforded an over-all picture of automobile manufacturing operations.

The fine planning and successful execution of the conference was effected largely by the efforts of the conference committee, which included the following personnel:

E. H. Vedder, *chairman*
H. I. Stanback, *publicity*
L. E. Donelson, *registration*
B. L. Wise, *treasurer*
Merle Spurrell, *hotels*
H. L. Lindstrom, *meetings facilities*
E. E. Zimmerman, *meetings facilities*
H. C. Hines, *hospitality*
C. N. Clark, *publication*
Myron Zucker, *local committee chairman*
G. W. Garman, *program*

Publicity—H. W. Snyder, H. W. Tietze, R. E. Young, E. M. Callender, J. S. Deffenbauth, J. H. Lamp, A. G. Turnbull, L. K. Stringham

Program—G. M. Chute, C. E. Smith, C. N. Clark, R. C. McMaster, R. C. Freeman, E. F. Steinert, F. J. Wells

Publications—G. I. F. Theriault, S. Shiozawa, W. E. Crawford, W. B. Kouwenhoven, J. C. Learman, S. Rothganger, J. R. Sellenberg, E. W. Davis

AIEE Director J. R. North (right) opened the AIEE conference of electric welding in Detroit, Mich., which was held December 6–8, 1948. Shown with him is Marvin Horne, of George R. Horne and Company, Dearborn, Mich., who is chairman of the AIEE Michigan Section

A group of welding men get together before the AIEE conference on electric welding in Detroit, Mich. From left to right they are H. I. Stanback, of the Square D Company, Milwaukee, Wis.; E. D. Kane, Detroit Edison Company; E. H. Vedder (chairman of the conference and also chairman of the AIEE electric welding committee), Westinghouse Electric Corporation, Buffalo, N. Y.; E. E. Zimmerman, Chrysler Corporation, Detroit, Mich.; C. N. Clark, Duquesne Light and Power Company, Pittsburgh, Pa.; and G. W. Garman, General Electric Company, Schenectady, N. Y.

Analysis of Registration, AIEE Electric Welding Conference, Detroit, Mich.

District	Members	Non Guests	Totals
1	21	26	47
2	11	31	42
3			
4		1	1
5*	95	228	323
6			
7	1		1
8		4	4
9	1	2	3
10	3	12	15
Total	132	304	436

* District in which conference was held.

Nucleonic and Medical Instrumentation Topic of Conference Held in New York

More than 500 people attended the highly successful AIEE/IRE conference on electronic instrumentation in nucleonics and medicine which was held in the Engineering Societies Building, 33 West 39th Street, New York, N. Y., November 29–December 1, 1948. Originally planned as two AIEE conferences; one on electronic aids to medicine, and the other on nucleonic instrumentation, the two were combined into a joint 3-day gathering with the Institute of Radio Engineers (*EE, Jul '48, pp 707–08*).

This was the third of the new type of general meetings known as "technical conferences" (*EE, Feb '48, p 189*), and was the first to be sponsored jointly by committees of AIEE and the Institute of Radio Engineers. These included two AIEE technical committees; the subcommittee on nucleonic instrumentation of the nucleonics committee and the subcommittee on electronic aids to medicine of the electronics committee; and the nuclear studies committee of the Institute of Radio Engineers. These three groups found an area of common interest and combined their efforts to run an interesting and informative conference.

Realizing that the subjects to be presented would be of interest to several groups of technical specialists, the planning committee arranged the program accordingly. Thus, the subjects covered in the first day's papers were of interest to medical people, those presented during the third day were directed to engineers and physicists, and the papers presented during the second day were such as to interest both medical and technical people. This arrangement proved quite convenient for it enabled busy medical and technical people to budget their time and attend the meeting on those days when their fields of interest were being covered.

The first day's sessions were presided over by Doctor W. A. Geohegan, Cornell University Medical College, New York, N. Y. The subjects discussed included various types of biological amplifiers and their requirements, and biological requirements in recording devices. Doctor G. W. Dunlap, General Electric Company, Schenectady, N. Y., presided over the second day's sessions which covered different aspects of nucleonic instrumentation including discussions of the various types of instruments used for detecting radiation as well as the techniques involved in their use. Health protection instrumentation also was discussed. The last day's sessions were presided over by H. H. Goldsmith, Brookhaven National Laboratory, Upton, N. Y. The subjects covered in this session included various types of counters such as proportional counters, electron multiplier counters, crystal counters, and electronic counting techniques, as well as other related subjects. A complete listing of the program appeared in a previous issue (*EE, Nov '48, p 1108*).

The technical sessions of the conference were held in the Engineering Societies' Building auditorium. An interesting exhibit of nuclear radiation instruments, provided by the Atomic Energy Commission, was on display in room 502 of the building. This display was attended by nearly all those who attended the conference.

At a meeting at Institute of Radio Engineers' headquarters after the conference (on December 7, 1948) the planning group of the conference met to discuss the results of the conference, and to make plans for future meetings. It was agreed unanimously that the conference was a success, and in view of this fact, more meetings of this type should be planned. It was decided that no pamphlet including the full text of the papers presented with discussions would be published. This had been done for the two previous AIEE conferences and the pamphlets are now available. ("Electron Tubes for Instrumentation and Industrial Use," price $3, $1.50 to AIEE members; and "Electrical Engineering Problems in the Rubber and Plastics Industries," price $3, $1.50 to AIEE members; both are available from the AIEE Order Department, 33 West 39th Street, New York 18, N. Y.) However, in this instance it was believed that the difficulties in obtaining the manuscripts and the complexities of getting clearances for some made it impractical.

The planning group made a number of suggestions for the next conference. A new planning group is to be organized, that will be charged with the responsibility of arranging the next conference in this field. In order to aid this new group a questionnaire is to be circulated among those who attended the conference inquiring as to their reactions to the conference along with suggestions for the subjects for the next conference.

The success of the meeting was largely attributable to the efforts of the planning group, which consisted of the following:

H. LeVine, E. E. Grazda, Virgil Graham, R. S. Gardner, James W. McRae, Milton E. Mohr, G. F. Maedel, Doctor J. D. Tebo, Professor Solomon Fishman, Ralph R. Batcher, Doctor J. J. Smith, Doctor G. W. Dunlap, Corbin Allardice, Doctor W. A. Geohegan, Doctor R. E. Lapp, R. L. Butenhoff, Adrian Dahl, H. H. Goldsmith, Doctor W. R. G. Baker, R. M. Bowie, Doctor W. F. Davidson, C. B. DeSoto

Analysis of Registration, Conference on Electronic Instrumentation in Nucleonics and Medicine

District	Members	Men Guests	Total
1	25	71	96
2	37	152	189
*3	35	163	198
4	2	25	27
5	4	15	19
6			
7		4	4
8	2		2
9		4	4
10	1	7	8
Totals	106	441	547

* District in which meeting was held.

AIEE PROCEEDINGS

Order forms for current AIEE *PROCEEDINGS* have been published in *ELECTRICAL ENGINEERING* as listed below. Each section of AIEE *PROCEEDINGS* contains the full, formal text of a technical program paper, including discussion, if any, as it will appear in the annual volume of AIEE *TRANSACTIONS*.

AIEE *PROCEEDINGS* are an interim membership service, issued in accordance with the revised publication policy that became effective January 1947 (*EE, Dec '46, pp 567–8; Jan '47, pp 82–3*). They are available to AIEE Student Members, Associates, Members, and Fellows only.

All technical papers issued as AIEE *PROCEEDINGS* will appear in *ELECTRICAL ENGINEERING* in abbreviated form.

Location of Order Forms	Meetings Covered
Apr '48, p 49A	Winter general
Aug '48, p 45A	Great Lakes District North Eastern District Summer general
Oct '48, p 43A	Pacific general Middle Eastern District
Dec '48, p 35A	Midwest general Southern District

Future AIEE Meetings

Winter General Meeting
Statler Hotel (formerly Pennsylvania Hotel)
New York, N. Y.
January 31–February 4, 1949
(Final date for submitting papers—closed)

AIEE Conference on the Textile Industry
Atlanta, Ga.
Spring, 1949

AIEE Conference on the Rubber and Plastics Industry
Akron, Ohio
March, 1949

AIEE Conference on the Industrial Applications of Electron Tubes
Buffalo, N. Y.
April 11–12, 1949

South West District Meeting
Baker Hotel, Dallas, Tex.
April 19–21, 1949
(Final date for submitting papers—closed)

AIEE Conference on the Textile Industry
Boston, Mass.
May 4, 1949

Summer General Meeting
New Ocean House, Swampscott, Mass.
June 20–24, 1949
(Final date for submitting papers—February 20)

Pacific General Meeting
Fairmont Hotel, San Francisco, Calif.
August 23–26, 1949
(Final date for submitting papers—April 23)

Midwest General Meeting
Netherland Plaza Hotel, Cincinnati, Ohio
October 17–21, 1949
(Final date for submitting papers—June 17)

Winter General Meeting
New York, N. Y.
January 30–February 3, 1950
(Final date for submitting papers—September 30)

North Carolina Section Holds Meeting in Charlotte

The AIEE Charlotte Subsection was host on December 3, 1948, to a meeting of the AIEE North Carolina Section which attracted a total attendance of 225 persons, including 107 students. The meeting included business and technical sessions, inspection trips, and a dinner meeting. At the speakers' table (in the background) during the banquet are shown, left to right: Professor W. J. Seeley, head of the electrical engineering department, Duke University; Professor W. D. Stevenson, electrical engineering department, North Carolina State College, and secretary, North Carolina Section; Doctor G. G. Brennecke, head, electrical engineering department, North Carolina State College, and chairman, North Carolina Section; D. A. Stentz, Duke University student who presented paper; B. V. Martin, Charlotte Subsection chairman and toastmaster; H. S. Dumas, president, Southern Bell Telephone Company; E. W. Olschner, president, Carolina Telephone and Telegraph Company; Mrs. Olschner; Mrs. Lamphe; Doctor Lamphe, dean of the engineering department, North Carolina State College

AIEE Nominating Committee to Meet During Winter Meeting

The nominating committee of the AIEE will meet at the Hotel Statler (formerly Pennsylvania), New York, N. Y., January 31, 1949, during the winter meeting, to nominate candidates for national offices to be voted on by the membership in the spring of 1949. Members of the committee follow.

Representing the board of directors are

J. H. Berry, Virginia Electric and Power Company, Norfolk, Va.

G. W. Bower, Public Service Electric and Gas Company, Newark, N. J.

C. W. Fick, General Electric Company, Cleveland, Ohio

Victor Siegfried, American Steel and Wire Company, Worcester, Mass.

Representing the geographical Districts:

1. R. V. Shepherd, General Electric Company, Schenectady, N. Y.

2. J. C. Strasbourger, Cleveland Electric Illuminating Company, Cleveland, Ohio.

3. R. T. Oldfield, Public Service Commission of New York, New York, N. Y.

4. C. P. Knost, Moloney Electric Company, New Orleans, La.

5. John H. Kuhlmann, University of Minnesota, Minneapolis, Minn.

6. J. O. Kammerman, South Dakota School of Mines and Technology, Rapid City, S. Dak.

7. P. G. Wallace, Texas Power and Light Company, Dallas, Tex.

8. J. P. Conner, Public Works Office, 11th Naval District Headquarters, San Diego, Calif.

9. Thomas Jordan, American Smelting and Refining Company, Garfield, Utah

10. E. A. Dillon, English Electric Company of Canada, Ltd., St. Catherines, Ontario, Canada

Alternates for board representatives are

J. L. Callahan, RCA Laboratories Division, Radio Corporation of America, New York, N. Y.

M. D. Hooven, Public Service Electric and Gas Company, Newark, N. J.

Alternate for District 6 representative

A. A. Little, Northwestern Bell Telephone Company Omaha, Nebr.

April Electron Tube Conference to Feature Industrial Applications

An AIEE conference on the industrial application of electron tubes will be held in the Statler Hotel, Buffalo, N. Y., on April 11 and 12, 1949. The conference will provide a means for electron tube users to discuss their mutual problems with control equipment designers and tube manufacturers.

The program for the first day will include a technical session on the application of electron tubes in control and other industrial equipment, an inspection trip to the new Westinghouse plant in Buffalo, and a presentation of papers by users describing their operating experience and maintenance.

The second day will be devoted to a discussion of the items which the equipment manufacturers consider in designing control and other equipment using tubes, followed by a technical session on methods used by electron tube manufacturers in building and rating tubes for industrial applications.

The conference is sponsored by the AIEE subcommittee on electron tubes of the electronic committee, and the subcommittee on electronic control of the industrial control committee jointly with the Niagara Frontier Section of the AIEE.

Midwest General Meeting Committee. According to a recent announcement, AIEE President E. S. Lee has appointed the following members of the Midwest general meeting committee for 1949:

E. S. Fields, *chairman;* R. J. Rockwell, *vice-chairman;* J. P. Quitter, *secretary;* W. H. McNutt, *treasurer;* J. C. Strasbourger; R. E. Stroppel; F. E. Wiatt; representatives of the Columbus, Dayton, Indianapolis, and Louisville Sections

Chairmen of the various committees:

A. C. Burroway, E. F. Nuezel, *technical program;* W. T. Pavely, *inspection trips;* S. B. Storer, *entertainment;* J. A. Noertker, *transportation;* D. T. Michael, *registration;* F. W. Willey, *finance;* R. E. Colado, *publicity;* Mrs. J. A. Noertker, *ladies;* H. E. Barnett, *hotel and equipment*

PERSONAL NOTES.....

Morris E. Leeds (A '01, F '26), inventor and chairman of the board of Leeds and Northrup Company, Philadelphia, Pa., has been named as the winner of the Edison Medal for 1948. The Edison Medal, one of the nation's top engineering honors, is awarded for meritorious achievement in electrical science, and was presented to Leeds "for his contributions to industry through development and production of electrical precision measuring devices and controls." He received the medal on February 2, 1949, at the AIEE winter general meeting in New York City. Leeds was born March 6, 1869, in Philadelphia, Pa., and received his bachelor of science degree from Haverford College, Philadelphia, in 1888. His education also included a year of advanced study at the University of Berlin, Germany, 1892–93. In 1936, Leeds received the honorary degree of doctor of engineering from the Polytechnic Institute of Brooklyn, N. Y. Entering early into the manufacture of electric measuring instruments and apparatus, he worked until 1899 for Queen and Company, and then set up the firm of Morris E. Leeds and Company, which in 1903 became Leeds and Northrup. He acted as president for that firm until 1939, at which time he became chairman of the board, the position he still holds. The company is now internationally known for its production of scientific instruments. Leeds also has been a pioneer in the development of the instrument industry in the United States, helping to found the Scientific Apparatus Makers of America, and acting as its president from

A. M. Zarem

J. W. Forrester

M. E. Leeds

1920 to 1926. He was also active in the starting of the journal now known as the *Review of Scientific Instruments*. A leader in employee-management relations, Leeds inaugurated several employee benefit plans as early as 1923, and during the depression years, was very active as an advisor to the government on means and methods of alleviating unemployment. For his services in this field, Leeds was presented with the Henry Laurence Gantt Medal by the Institute of Management in 1936. He also received the First Rotary Award from the Rotary Club of Philadelphia in June 1945, "in recognition of outstanding accomplishments . . . in business, education, industrial management, and world citizenship." For his industrial and technical accomplishments, Leeds was recognized by the Franklin Institute for the invention of the Leeds and Northrup mechanical recorder, and was presented with the institute's Longstreth Medal in 1920. In 1946, he was the recipient of The American Society of Mechanical Engineers Medal, one of that society's highest awards. A Fellow of the American Society for the Advancement of Management, Leeds also holds membership in the American Physical Society, the Academy of Natural Sciences, American Society for Steel Treating, The Franklin Institute, American Philosophical Society, Scientific Apparatus Makers of America, Metal Manufacturers Association of Philadelphia, American Academy of Arts and Sciences, and Phi Beta Kappa and Beta Gamma Sigma fraternities. As part of his civic duties, he has served of the Board of Public Education of Philadelphia since 1938, and as a member of the board of managers of Haverford College since 1909.

Abe M. Zarem (A '43), manager and chairman of physics research for the Stanford University Research Institute, Los Angeles, Calif., has been selected as the "Outstanding Young Electrical Engineer of 1948" by the Eta Kappa Nu jury of award. Valedictorian of the 1939 class of the Armour Institute of Technology, now the Illinois Institute of Technology, he was awarded a scholarship for graduate study in electrical engineering at the California Institute of Technology, Pasadena. For two years, Zarem instructed on the senior and graduate level in physics, electrical engineering, and mathematics. Under the direction of Doctor Royal W. Sorenson, professor of electrical engineering at the institute, Zarem received the doctor of philosophy degree "magna cum laude" for research on the physical properties of the electric spark. He then left the institute to become research and development engineer for the electronic rectifier division of the Allis-Chalmers Manufacturing Company, Milawukee, Wis. After designing several rectifier installations, he developed an electrical control method for monitoring power systems and indicating faults. He also conducted extensive research on the gaseous conduction of electricity, particularly mercury vapor, and developed specialized electrical instrumentation for studying mercury arc conduction. Zarem then invented what he calls "an automatic oscillograph with a memory" which is triggered by random changes in the phenomena being studied, and has attached an automatically operated camera for recording purposes. The instrument is used to study electric transients at irregular and unpredictable intervals. He also invented an automatic control system for the operation of photographic equipment while at the Allis-Chalmers Company, and organized a company training program in mathematics and physics. In May 1945, Doctor Zarem returned to the California Institute of Technology to become research engineer and group leader of the Manhattan District project. His work with that group is still on the secret list, but it is known that he directed the design and development of electronic components and specialized electronic techniques. He then joined the staff of the United States Naval Ordnance Test Station, Pasadena, as head of basic and electrical engineering research for the electronics group. In January 1947, Zarem was named to head the electrical section of the newly formed Physical Research Division. He returned again to the study of transient electric discharges and proceeded to develop a method for photographing them. He developed an electro-optical shutter and camera control capable of submicrosecond effective exposure times, which opened the field of "synchronized microtime photography" to the United States Navy. At the same time he designed a leakproof Kerr cell shutter of small dimensions and capable of effective exposure times as low as 8×10^{-9} second. The invention of the Zarem camera for obtaining a sequence of photographs each with an effective exposure time down to 0.000,000,001 second, and with framing rates up to 100,000,000 per second, is probably his most outstanding achievement. This camera is used to study intense light sources and other phenomena. As an outgrowth from this field, Zarem also invented an unconventional photoelectric trigger for timing problems, and a photoelectric synchronizer for spectral studies of electric discharges as a function of tie. In addition to this work, he has done considerable consultation work in the fields of electromagnetics, transient electrical studies, gaseous discharge phenomena, oscillography, and electronic pulsing techniques. He also has conducted test work in equipment for measuring blast pressures, and electrical characteristics in the breakdown of natural minerals, plastics, and oils. As the manager and chairman of physics research at the Stanford Research Institute, Doctor Zarem is responsible for the co-ordination of technical and administrative activities of his office in such fields as acoustics, electricity, magnetism, light and optics, spectroscopy, analytical mechanics, and heat transfer. His list of patents is long and still growing. Among his professional affiliations, Zarem includes membership in the American Institute of Physics, the Institute of Radio Engineers, and Eta Kappa Nu, Sigma Xi, and Tau Beta Pi fraternities.

Jay W. Forrester (A '42), associate director of the servomechanisms laboratory, Massachusetts Institute of Technology, Cambridge, has received an honorable mention award in the annual Eta Kappa Nu Recognition of Outstanding Young Electrical Engineer. After graduating first in his class in 1939 from the University of Nebraska, he came to the Massachusetts Institute of Technology as a graduate student and research assistant in the department of electrical engineering and worked on the development of high-voltage electrostatic generator, in the few-megavolt range and the application of these generators to the treatment of cancer. Late in 1940, Forrester was assigned to work on a servomechanism for gunfire control, and developed an hydraulic type subsequently used extensively by both the United States Army and Navy on antiaircraft weapons. This original servo group was expanded during the war to become the Massachusetts Institute of Technology servomechanisms laboratory, with which Forrester helped solve shipboard radar stabilization problems. In 1943, he helped develop an antenna drive for a new form of fighter director radar system for the Massachusetts Institute of Technology radiation laboratory. This equipment was tested by Forrester personally on the aircraft carrier, *USS Lexington*, during the invasion of the Marshall and Gilbert Islands in the Pacific theater of operations. For the past three years, he has been building an analogue simulation system which permits test pilots to get the realistic feel of new controls and flight instruments. Forrester's major contribution has been the development of 2-stage mechanical integrators and potentiometer multipliers with extremely high sensitivities. The group of 200 persons that he heads now is working on a new electronic digital computor technique to solve aircraft analyzer simulator problems. Forrester has authored 35 technical documents and has had several patents issued in his name. He is on the technical committee of the Institute of Radio Engineers, and holds membership in the Association for Computing Machinery and the American Association for the Advancement of Science.

Milton E. Mohr (A '39), member of the technical staff, Bell Telephone Laboratories, Inc., New York, N. Y., has received an honorable mention award in the annual Eta Kappa Nu Recognition of Outstanding Young Electrical Engineers. A 1938 graduate from the University of Nebraska, he compiled the highest academic average in the history of the school. Mohr joined the Bell Telephone Laboratories in 1938 and developed basic elements for radically new automatic switching systems and electron beam tubes for signal analysis and coding for pulse code modulation. He has done considerable work on frequency modulation methods and counting and coding circuits. During World War II, Mohr was responsible for major developments in electronics and electric devices, many of which are still on the secret list. More recently, his work has been notable in the use of negative resistances and newly developed transitors. He already holds 13 American patents and has seven more in preparation. Aside from Mohr's technical accomplishments, his honorable mention was given for his civic and social interests which are many and diversified. Active in AIEE, he is at present chairman of the basic sciences division of the New York City Section. Mohr also holds membership in the Institute of Radio Engineers, the Summit (N.J.) Association of Scientists, and Sigma Xi fraternity.

L. M. Smith (M '36), vice-president and director of public relations of the Alabama Power Company, Birmingham, has been chosen president of the Birmingham chamber of commerce. His selection was based upon his contributions to civic welfare and to his position as one of the South's foremost business spokesmen. A graduate of the University of Alabama in 1916, Smith was with the Tennessee Iron and Railroad Company until 1923 when he joined the Alabama Power Company as a draftsman in the engineering department. In time he became chief electrical engineer, director of public relations, and finally, vice-president. A past chairman of the AIEE Alabama Section, he served as program committee chairman at the 1948 Southern District meeting. He also holds membership in the American Association for the Advancement of Science, the Public Relations Society, and the National Council for Community Improvement.

F. E. Brooks (A '38, M '42) has been named chief engineer of the New York Telephone Company's Manhattan-Bronx-Westchester area. Brooks previously held the same position for that company's Long Island area. He joined the company in 1912, after graduation from the Case Institute of Technology. From 1942 to 1944, he held the position of assistant vice-president, co-ordinating wartime protection of company plant and personnel and related matters. He is a member of Sigma Nu and Eta Kappa Nu fraternities, and the Engineers' Club of New York.

C. A. Atherton (M '42), Westinghouse Electric International Company, has been elected honorary secretary of the International Commission of Illumination at a recent meeting. A graduate of Worcester Polytechnic Institute, Atherton was technical director for many years for the international group of lamp manufacturers known as Phoebus and located in Geneva, Switzerland. He returned to the United States at the outbreak of World War II and was associated with the Reynolds Metals organization before joining the Westinghouse International Company. He was chairman of the Illuminating Engineering Society handbook committee which brought out the first comprehensive handbook on lighting.

R. M. Fairfield (M '46) has been appointed general manager of the St. Helens Cable and Rubber Company, Ltd., and of Veedip Ltd., both of Slough, England. Prior to joining the Callender Cable and Construction Company, Ltd., Erith, Kent, England, in 1937, Fairfield had extensive experience in high-voltage cables and radio valve production. He took charge of the technical organization of the rubber cable factory of the Callender Company in 1937, and included the paper cable factory in 1942. In 1945, he became chief engineer in charge of processes and designs, the position he held until this recent appointment.

R. L. Laudenslager (A '32), formerly electrical engineer for Stone and Webster Engineering Corporation, Boston, Mass., has joined the faculty of the University of Connecticut, Storrs, as assistant professor of electrical engineering. Prior to joining Stone and Webster, Laudenslager was with both the Consolidated Edison Company of New York, Inc., and the Brooklyn Edison Company.

H. F. Dart (A '20, M '26), office manager, electronic tube engineering department, Westinghouse Electric Corporation, Bloomfield, N.J., has been elected a trustee of the Technical Societies Council of New York, Inc. He is a delegate to the council, representing the New York section of the Institute of Radio Engineers. He also is serving as a member of the 1948–49 AIEE electronics committee.

C. E. Sutton, Jr. (A '39, M '45), district transformer specialist, central station department, General Electric Company, Philadelphia, Pa., has been appointed assistant manager of the power transformer sales division of that same company.

C. W. Jones (A '30, M '44), former executive assistant, has been elected a vice-president of the New England Electric System, Boston, Mass. He joined that utility in 1927, and during World War II was chief of the equipment product branch of the Office of War Utilities.

Y. T. Chaney (A '40, M '45) has been appointed manager of distribution systems sales for the Trumbull Electric Manufacturing Company, Plainville, Conn. He joined the firm in 1937, and has been serving as resident engineer since 1945.

A. P. S. Bellis (A '26), chief engineer, John A. Roebling's Sons Company, Trenton, N.J., has announced his retirement. He has been with the company since 1900 and is on the insulated conductors committee of the AIEE for 1947–48. He is also a member of the American Society for Testing Materials.

M. S. Carlson (M '41), formerly appliance engineer, is now assistant sales manager for the I-T-E Circuit Breaker Company, Philadelphia, Pa. He has been very active in the air circuit breaker and power circuit breaker sections of the National Electrical Manufacturers Association.

H. Fletcher (M '23, F '30), director of physical research, Bell Telephone Laboratories, Inc., New York, N.Y., has been appointed a member of the National Research Council, division of engineering and industrial research. In 1941–42, he served on the AIEE application of electricity to therapeutics committee.

H. B. Wolf (A '26, F '45), superintendent of maintenance, Duke Power Company, Charlotte, N.C., since 1941, has been appointed operating superintendent of that utility. He has been with the company for the past 32 years. Wolf was on the AIEE Edison Medal committee and the AIEE committee of the award of Institute prizes in 1945–47, and the AIEE Sections committee in 1946–47.

W. S. Edsall (M '19), formerly president, is now president and general manager of the Chase-Shawmut Company, Newburyport, Mass. He served on the AIEE protective devices committee in 1923–24, 1927–36, and 1942–44.

L. M. Smith

F. E. Brooks

M. E. Mohr

F. W. Tatum (A '42, M '45), formerly an instructor at Southern Methodist University, Dallas, Tex., has been appointed an associate professor of electrical engineering. For 11 years prior to joining the university staff, Tatum was section head of the American District Telegraph Company's design and development engineering department in New York, N.Y.

A. W. Cruse (M '38), assistant vice-president of the International Telephone and Telegraph Corporation, New York, N.Y., has been elected president of the Radio Corporation of Puerto Rico, a subsidiary, and also will serve on the board of directors of that company. He was a member of the AIEE communications committee in 1941–42.

S. O. Thomas (M '48) has been appointed chief motor engineer for the Hobart Manufacturing Company, Troy, Ohio. He joined the company in 1935 in the motor engineering department and has been designing motors for use in food and kitchen machines since that time. During World War II, Thomas did extensive specialized motor development of war materials for the United States Army Ordnance Department.

O. W. Graham (A '45) has been named president of Instruments, Inc., Tulsa, Okla., the company he helped organize to distribute nationally his invention, the Gagetron, a gamma ray level control instrument. The organization also will design and manufacture all types of electronic and mechanical instruments. Graham is the recipient of the Presidential Certificate of Merit for his work in developing the Penetron, an electronic device, during World War II at the Texas Development Company's research laboratory.

M. F. Beisber (A '37, M '45), sales manager, transformer division, Line Material Company, Milwaukee, Wis., has been promoted to assistant vice-president and will continue to supervise transformer division sales. A 1928 graduate of the Illinois Institute of Technology, Beisber joined the Line Material Company in 1933 and has been a transformer specialist for that firm in branch offices throughout the United States.

L. F. Hickernell (A '25, F '34) has been named chief engineer in charge of engineering and research policy for the Anaconda Wire and Cable Company, Hastings-on-Hudson, N.Y. He will be aided by **L. L. Carter** (A '29, F '38) and **D. E. Allen** (A '23). The company also announces the appointment of **A. A. Jones** (M '46) as manager of the engineering department to supervise directly engineering and research operations.

OBITUARY • • • •

Frank K. Brainard (A '08, M '12, F '38), a member of the Allis-Chalmers Company's motor and generator engineering section, Milwaukee, Wis., since 1909, died December 6, 1948. He was born in Flint, Mich., September 5, 1880. He received his degree in mechanical engineering from the Michigan Agricultural College in 1903, and then received a postgraduate degree in electrical engineering from the University of Wisconsin in 1907. He then served as assistant to the power superintendent of the Detroit (Mich.) United Railway, holding that position until 1908. In that year, Brainard joined the consulting engineering firm of C. L. Weil and Company, also of Detroit, but became an electrical engineer for the Allis-Chalmers Company from 1909 to 1915. During the years 1915–17, Brainard was professor of electrical engineering at Marquette University, but in that latter year, he returned to the employ of the Allis-Chalmers Company. For the past 30 years, Brainard had been working principally on synchronous machine design, especially the electrical design work necessary for smaller synchronous motors and generators. He also had done considerable work on small and medium size alternators for that company. Brainard's work, both in the electrical and mechanical engineering fields, resulted in many technical papers and publications in scientific and engineering journals.

Arthur F. Riggs (M '16, F '45), district engineer, apparatus department, Central District, General Electric Company, Chicago, Ill., died October 30, 1948. Born in Orangeburg, S. C., on April 19, 1878, he was graduated from the Clemson Agricultural College in 1900 with a degree in mechanics and engineering. Immediately following graduation, Riggs became engineer for the Municipal Light and Water Company of Orangeburg, with responsibility for power plant maintenance and all transmission and distribution lines, but in 1901, he joined the General Electric Company's testing department at Schenectady, N. Y., as a test engineer. Sent to that company's Central District office in Chicago in 1903, Riggs was construction foreman until 1909, and engineer in charge of all electrical field work in the district from that year until 1915. For the next four years, he was assistant to the district engineer and then acting district engineer. In 1924, Riggs was named district engineer, the position he held until retiring on March 1, 1947.

Walter E. Knouse (A '27), senior engineer in the electrical engineering division, Philadelphia (Pa.) Electric Company, died December 4, 1948. He was born in Sandy Run, Pa., on April 3, 1893, and was graduated from Lehigh University in 1924 with the degree of electrical engineer. In that same year he was employed by the Philadelphia Electric Company, and after working in several branches of the electrical engineering division, was placed in charge of transformer engineering in 1942. From 1927 on, Knouse also taught electrical engineering subjects at the Drexel Institute of Technology evening school in Philadelphia. In 1941, he was elected president of the Philadelphia Electric Company's Employees Association. At the time of his death, Knouse was a member of the AIEE protective devices committee, and was chairman of the prize papers committee of the AIEE Philadelphia Section.

Hendrik J. van der Bijl (M '17), chairman of the Electricity Supply Commission of South Africa, Johannesburg, died December 2, 1948. He was born in Pretoria, South Africa, on November 23, 1887, and received his doctor's degree in 1912 from the University of Leipzig, Germany, after preparatory study in physics and mathematics at Victoria College in South Africa, and the University of Halle, in Germany. In 1912–13, van der Bijl was an instructor of physics at the Royal High School of Technology, Dresden, Germany, but then came to the United States to help establish the transcontinental telephonic communication line for the Western Electric Company. In 1920, he was persuaded to return to South Africa by General Jan Smuts and became technical adviser on technical development, and in 1923, was named chairman of the newly formed Electricity Supply Commission, the position he held until his death. He also was associated with several South African industries.

Peter White (A '37), electrical engineer for Ebasco Services, Inc., New York, N. Y., died December 12, 1948. He was born March 12, 1914, in Chicago, Ill., and received his bachelor of science and master of science degrees from the Massachusetts Institute of Technology, the latter in 1936. He joined the Phoenix Engineering Corporation, New York, N. Y., in that year and was made assistant to the electrical engineer. He served with the United States Army in World War II, and then returned to civilian life and his position with Ebasco Services, Inc.

William C. Sterne (A '23, M '32), president of the Arvada Electric Company, Denver, Colo., died November 28, 1948. A graduate of Harvard University, he was born in Peru, Ind., on December 13, 1869. From 1903 until 1926, Sterne was general manager and executive officer of several public utilities. He became the president of the Arvada Electric Company in 1911, and held that position until his death. One of his major interests was for the progress and development of the electrical industry in Colorado, and for the past 15 years, Sterne served as treasurer of the Rocky Mountain Electrical League.

Willard H. MacGregor (A '97, M '32), a Life Member of the Institute, died December 19, 1948. A native of New York, N. Y., he was born May 3, 1865. Receiving his mechanical engineering degree from Stevens Institute in 1896, MacGregor worked under Doctor Cary Hutchinson as a draftsman until 1897. He became a designer of air circuit breakers for the Ward Leonard Electric Company for two years, and then was with the Cutler Hammer Manufacturing Company until 1901. From that year until 1916, MacGregor was with the detail department of the Westinghouse Electric Corporation (then the Westinghouse Electric and Manufacturing Company), specializing in switchboard design. From 1917 until 1930, he was advisory engineer for Deering Milliken and Company, supervising steam power equipment for over 30 enterprises. MacGregor's professional affiliations included membership in The American Society of Mechanical Engineers and Tau Beta Pi fraternity.

MEMBERSHIP. . .

Recommended for Transfer

The board of examiners at its meeting of December 16, 1948, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the secretary of the Institute. A statement of valid reasons for such objections must be furnished and will be treated as confidential.

To Grade of Fellow

Cordray, R. E., chge. of relay engg., General Electric Co., Phila., Pa.
Zippler, W. N., chief elec. engr., Gibbs & Cox, Inc., New York, N. Y.

2 to grade of Fellow

To Grade of Member

Ankrom, W. R., industrial power engr., The Ohio Power Co., Lima, Ohio.
Ankrum, P. D., prof. of elec. engg., Cornell Univ., Ithaca, N. Y.
Armentrout, L. S., supt. elec. dept., City of Harrisonburg, Harrisonburg, Va.
Cardwell, G. P., consulting & application engr., Westinghouse Elec. Corp., Detroit, Mich.
Carl, E. W., senior layout designer, The Glenn L. Martin Co., Baltimore, Md.
Carter, E. T., design engr. "A", Boeing Airplane Co., Seattle, Wash.
Cronin, L. D., elec. engr., Ebasco Services, Inc., New York, N. Y.
Day, H. B., co-ordinator of contracts & standard practices, Pennsylvania Power & Light Co., Allentown, Pa.
Getting, M. P., Jr., assistant to works manager, Allis-Chalmers Mfgr. Co., Pittsburgh, Pa.
Grove, A. W., asst. prof. of elec. engg., Univ. of Missouri School of Mines & Metallurgy, Rolla, Mo.
Hero, A. A., partner, Comfortair Co., New Orleans, La.
Keefe, W. E., application engr., General Elec. Co., Chicago, Ill.
King, D. E., assistant engr., Allis-Chalmers Mfgr. Co., West Allis, Wis.
McGreer, T. H., consulting & application engr., Westinghouse Elec. Corp., Chicago, Ill.
Moore, R. W., industry engr., Westinghouse Elec. Corp., East Pittsburgh, Pa.
Pearson, S. I., assistant prof. of elec. engg., University of Colorado, Boulder, Colo.
Peterson, H. C., electronic engr., Navy Dept., Washington, D. C.
Strong, H. D., sales engr., central station div., General Elec. Co., Los Angeles, Calif.
Ward, A. B., instructor, school of engg., Purdue Univ., West Lafayette, Ind.
Wyatt, R. M., branch mgr., Westinghouse Elec. Corp., Allentown, Pa.

20 to grade of Member

Applications for Election

Applications have been received at headquarters from the following candidates for election to membership in the Institute. Any member objecting to the election of any of these candidates should so inform the secretary before February 21, 1949, or April 21, 1949, if the applicant resides outside of the United States, Canada, or Mexico.

To Grade of Member

Alexander, S. N., Nat'l Bureau of Standards, Washington, D. C.
Bevan, G. T., General Elec. Co., Schenectady, N. Y.
Cabrera, J. M., Cinco De Mayo 32 Office 416, Mexico City, Mexico.
Cook, E. C., Texas Meter & Device Co., Waco, Tex.
Craig, G. D., II, Square D Co., Elmhurst, N. Y.
Darley, W. G., 301 Nalle Bldg., Austin, Tex.
Dealey, J., Ebasco Services Inc., New York, N. Y.
Drazen, M., Drazen & Assocs., St. Louis, Mo.
Eglington, W., Westinghouse Elec. Intl. Co. of New York, Caracas, Venezuela, S. A.
Estes, P. H., General Elec. Co., Schenectady, N. Y.
Gardner, R. S., A. I. of E. Es., New York, N. Y.
Gillis, N. W., G.M.C., Truck & Coach Div., Pontiac, Mich.
Hodgson, A. W., Westinghouse Elec. Corp., Cheektowaga, N. Y.
Jones, C. C., National Carbon Co., Inc., Fostoria, Ohio
Kahn, D. A., Curtiss-Wright, Columbus, Ohio
Lesher, W. C., General Elec. Co., Pittsfield, Mass.
Lilley, N. E., Central Elec., Shawinigan Falls, Quebec, Canada
Long, T. P., Western Elec. Co., Inc., Allentown, Pa.
Matheny, J. D., Wisconsin Tel. Co., Milwaukee, Wis.
McCarthy, T., Electricity Supply Board, Limerick, Ireland
Peterson, H. W., N. Y. State Elec. & Gas Corp., Elmira, N. Y.
Poole, T. W., General Elec S. A., Mexico Federal District, Mexico
Riley, W. J., Stromberg-Carlson Co., Rochester, N. Y.
Romeira, M. P., General Elec., Rio de Janeiro, Brazil, S. A.
Sen, S. K., General Elec. Co., Schenectady, N. Y.
Stein, D. B., North Dakota State College, Fargo, N. D.
Stovall, J. R., Jr., Tinius Olsen Testing Machine Co., Philadelphia, Pa.
Tetherow, C. L., Underwriter's Labs., Inc., Chicago, Ill.
Thwaite, W. E., Jr., Research Corp., Chicago, Ill.
Tun, U. A., c/o The Secretary, Government Cotton Spinning & Weaving Factory Board, Burma
Woodard, W. E., Southwestern Bell Tel. Co., Dallas, Tex.

31 to grade of Member

To Grade of Associate

United States and Canada

1. North Eastern

Adams, R. H., General Elec. Co., Schenectady, N. Y.
Annis, R. R., Allis-Chalmers Mfg. Co., Boston, Mass.
Bennett, W. C., General Elec. Co., Schenectady, N. Y.
Bishop, T. J., Western Mass. Elec. Co., Springfield, Mass.
Boutilier, E. F., Conn. Light & Power Co., New Milford, Conn.
Christopherson, W. A., General Elec. Co., Schenectady, N. Y.
Coates, H. K., 273 Main St., Nashua, N. H.
Cohen, J., Republic Steel Co., Buffalo, N. Y.
Collamore, F. N., Westinghouse Elec. Corp., Buffalo, N. Y.
Cooney, J. L., Jr., Corning Glass Works, Corning, N. Y.
Dickson, H. T., Stone & Webster Engg. Corp., Boston, Mass.
Drum, J. J., General Elec. Co., Pittsfield, Mass.
Edward, J. A., General Elec. Co., Pittsfield, Mass.
Field, E. W., Stromberg-Carlson Tel. Co., Rochester, N. Y.
Firschein, O., U. S. Engrs., Mount Morris, N. Y.
Forshee, L. A., N. Y. State Elec. & Gas Corp., Hornell, N. Y.
Gabrielson, F. L., Connecticut Coke Co., New Haven, Conn.
Goodale, E. E., General Elec. Co., Schenectady, N. Y.
Govindan, T. M., General Elec. Co., Schenectady, N. Y.
Grunes, S., Jackson & Moreland Co., Boston, Mass.
Herrick, W. C., N. Y. State Elec. & Gas Corp., Binghamton, N. Y.
Hobart, R. F., General Elec. Co., Schenectady, N. Y.
Honor, J. J. General Elec. Co., Lynn, Mass.
Kelly, L. F., Trumbull Elec. Co., Brookline, Mass.
Keller, R. A., Eastman Kodak Co., Rochester, N. Y.
Kowilich, M., New York State Elec. & Gas Corp., Elmira, N. Y.
Leon, J., Manning, Maxwell & Moore, Bridgeport, Conn.
Lephakis, A. J. (Student), Mass. Inst. of Tech., Cambridge, Mass.
Levins, D. B., General Elec. Co., Lynn, Mass.
Lowe, T. J., Boston Edison Co., Boston, Mass.
Lowenstein, M. J., General Elec. Co., Lynn, Mass.
Martiny, W. J., Jr., General Elec. Co., Lynnfield, Mass.
Mayo, S. J., Univ. of Maine, Orono, Maine
McMorrow, C. F., Rensselaer Polytechnic Inst., Troy, N. Y.
Moy, M., Stone & Webster Engg. Corp., Boston, Mass.
Pucci, T. D., Pucci Elec. Co., Inc., Westerly, R. I.
Riley, C., General Elec. Co., West Lynn, Mass.
Rines, B. P., Univ. of Mass., Amherst, Mass.
Rosenberg, A. J., General Elec. Co., Pittsfield, Mass.
Ross, F. T., I. R. M. Corp., Endicott, N. Y.
Rutledge, H. D., General Elec. Co., Schenectady, N. Y.
Scrafford, R. L., Cornell Aeronautical Lab., Buffalo, N. Y.
Seaver, J. D., General Elec. Co., West Lynn, Mass.
Seddon, B., Jr., General Elec. Co., Schenectady, N. Y.
Seymour, D. B., Westinghouse Elec. Corp., Buffalo, N. Y.
Slagter, H. C., General Elec. Co., Pittsfield, Mass.
Tompsett, D. H., Buffalo-Niagara Elec. Corp., Buffalo, N. Y.
Wise, K., General Elec. Co., Syracuse, N. Y.
Wyks, J. R., General Elec. Co., Schenectady, N. Y.

2. Middle Eastern

Acker, C. R., Line Material Co., Zanesville, Ohio
Alderton, K. R., Celanese Corp. of America, Cumberland, Md.
Aike, R. J., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Allen, W. H., Westinghouse Elec. Corp., Sharon, Pa.
Anderson, W. S., Westinghouse Elec. Corp., Baltimore, Md.
Baeslack, A. J., Carnegie Inst. of Technology, Pittsburgh, Pa.
Beck, P. A., Nat'l. Bureau of Standards, Washington, D. C.
Benner, R. H. 2nd, Johns Hopkins Univ., Baltimore, Md.
Berkowitz, R. S., Univ. of Pennsylvania, Philadelphia, Pa.
Bramblett, G. E., Jr., Union Carbide & Carbon Corp., Alloy, W. Va.
Brandt, N. H., Euclid Crane & Hoist Co., Euclid, Ohio
Buescher, B. E., Sylvania Elec. Products, Inc., Emporium, Pa.
Butler, M. E., Frigidaire Div., GMC, Dayton, Ohio
Byrne, R. M., Goodyear Aircraft Corp., Akron, Ohio
Christ, J. L., Berger Engg. Co., Pittsburgh, Pa.
Christmann, E. R., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Conroy, G. J., Edwin L. Wiegand Co., Pittsburgh, Pa.
Dawson, L. L. (re-election) Western Elec. Co., Allentown, Pa.
De Grand, R. A., Westinghouse Elec. Co., Lima, Ohio
Dertinger, E. F., Bendix Radio Div., Towson, Md.
Dorris, G. J., Jr., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Dunbar, W. J., I.T.E. Circuit Breaker Co., Philadelphia, Pa.
Fatabrook, R. E., Allen Elec. Co., Cleveland, Ohio
Farrar, C. E., United Engineers & Constructors, Philadelphia, Pa.
Fjelstad, H., Jr., Westinghouse Elec. Corp., Pittsburgh, Pa.
Fogelberg, A. E., Jr., Univ. of Delaware, Newark, Del.
Fox, D. H., Western Elec. Co., Allentown, Pa.
Fox, J. W., Virginian Railway Co., Princeton, West Va.
Frankfather, B. A., Elec. Auto-Lite Co., Toledo, Ohio
Gifford, J. H., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Hanzel, A., The Osborn Engg. Co., Cleveland, Ohio
Happold, T. W., I.T.E. Circuit Breaker Co., Philadelphia, Pa.
Harris, J. D., Jr., Sperry Gyroscope Co., Baltimore, Md.
Holt, R. C., Dayton Power & Light Co., Dayton, Ohio
Hoyt, A. G., General Elec. Co., Baltimore, Md.
Johnson, E. R., Jr., Westinghouse Elec. Co., E. Pittsburgh, Pa.
Johnson, R. N., Westinghouse Corp., E. Pittsburgh, Pa.
Jones, F. L., The Hoover Co., N. Canton, Ohio
Katz, B., Bethlehem Steel Co., Sparrows Point, Md.
Kemeny, G. A., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
King, H. L. P., Jr., Potomac Elec. Power Co., Washington, D. C.
Kish, C. B., Inland Manf. Div., GMC, Dayton, Ohio
Koch, F. W., Consolidated Gas, Elec. Light & Power Co. of Baltimore, Baltimore, Md.
Kromm, R. F., Bethlehem Steel Co., Sparrows Point, Md.
Lewis, W. M., Jr., Scioto Engg. Co., Scioto ville, Ohio
Mark, D. G., Dayton Power & Light Co., Dayton, Ohio
Markel, R. A., Jr., Philadelphia Elec. Co., Philadelphia, Pa.
Markowski, M. J., Reliance Elec. & Engg. Co., Cleveland, Ohio
Miller, F. C., General Elec. Co., Baltimore, Md.
Moskowitz, L. R., Westinghouse Elec. Supply Co., Pittsburgh, Pa.
Mozuch, J. H., Allis-Chalmers Mfg. Co., Pittsburgh, Pa.
Niki, T., General Elec. Co., Philadelphia, Pa.
Novinger, Q. D., Pennsylvania Power & Light Co., Allentown, Pa.
Olson, C. R., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Opalenik, J. J., Westinghouse Elec. Corp., Mansfield, Ohio
Pakkanen, L. R., 820 E. Lutton St., New Castle, Pa.
Puette, J. D., Clark Controller Co., Cleveland, Ohio
Quayle, J. C., Cleveland Elec. Illuminating Co., Cleveland, Ohio
Ragan, A. T., Jr., Carbide & Carbon Chems. Corp., Charleston, W. Va.
Ramadell, C. B., General Elec. Co., Baltimore, Md.
Rau, F. J., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Reed, R. J., Delco Products Div. of G.M.C., Dayton, Ohio
Rice, R. H., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Roehrer, C. R., Jr., Clark Controller Co., Cleveland, Ohio
Roney, J. F., I.T.E. Circuit Breaker Co., Philadelphia, Pa.
Roughen, R. C., Allis-Chalmers Mfg. Co., Pittsburgh, Pa.
Rudolph, H. E., Westinghouse Elec. Co., Sharon, Pa.
Rumsey, J. A., Northern Pennsylvania Power Co., Towanda, Pa.
Sanford, A. M., Ohio Brass Co., Mansfield, Ohio
Saslaw, R. L., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Schmidt, A. D., Consolidated Gas & Elec. Co. of Baltimore, Baltimore, Md.
Smith, A. W., Jr., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Smith, D. R., Jr., Northern Pennsylvania Power Co., Towanda, Pa.
Sneed, J. G., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Thompson, J. H., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Tice, W. C., General Elec. Co., Erie, Pa.
Turrell, D. W., Penna. Power & Light Co., Sunbury, Pa.
Vinton, B. W., General Elec. Co., Euclid, Ohio
Volpe, R. W., General Elec. Co., Erie, Pa.
Waters, R. W., General Elec. Co., Baltimore, Md.
Webster, G. A., Sperry Gyroscope Co., Baltimore, Md.
Wellard, L. C., Molded Insulation Co., Philadelphia, Pa.
Werth, M. W., Glen L. Martin Co., Baltimore, Md.
Westen, T. T., I.T.E. Circuit Breaker Co., Philadelphia, Pa.
Wollock, M., General Elec. Co., Cleveland, Ohio
Wood, H. N., Ideal Elec. & Mfg. Co., Mansfield, Ohio
Wright, D. A., School of Law, Univ. of Pittsburgh, Pittsburgh, Pa.
Wynne, W. T., Naval Air Development Station, Johnsville, Pa.
Yang, T., Univ. of Toledo, Toledo, Ohio
Ziegler, R. S., General Elec. Co., Philadelphia, Pa.

3. New York City

Armstrong, L. L., Westinghouse Elec. Corp., Bloomfield, N. J.
Auvermann, H. J., Lt., Signal Corps, Ft. Monmouth, N. J.
Beri, S., Dept. of the Army, Ft. Monmouth, N. J.
Bier, W. J., Geo. G. Sharp, New York, N. Y.
Bogenrief, W. R., American Bureau of Shipping, New York, N. Y.

Callahan, J. F., N. Y. State Electric & Gas Corp., New York, N. Y.
Drechsler, F. S., Ferranti Elec. Inc., New York, N. Y.
Eidinger, M. W., The Kellex Corp., New York, N. Y.
Elderkin, C. J., Intl. Tel. & Tel. Co., New York, N. Y.
Engel, G. F., John A. Roebling's Co., Trenton, N. J.
Freeman, H., Sperry Gyroscope Co., Great Neck, L. I., N. Y.
Gross, K. W., C. C. N. Y., New York, N. Y.
Hess, H. L., Western Union Tel. Co., New York, N. Y.
Horowitz, J., Sperry Gyroscope Co., Great Neck, N. Y.
Huttenlocher, H. J., Jr., Polytechnic Inst. of Bklyn., Brooklyn, N. Y.
Ku, W. S., Public Service Elec. & Gas Co., Newark, N. J.
Lee, N., General Cable Corp., Bayonne, N. J.
Novick, G., Polytechnic Research & Development Co. Inc., Brooklyn, N. Y.
Olie, C. H., Westinghouse Elec. Corp., Newark, N. J.
Olive, B. B., Westinghouse Elec. Int'l Co., New York, N. Y.
Pierce, H. W. (re-election), Wagner Elec. Corp., New York, N. Y.
Sakate, F. S., Civil Aeronautics Admin., New York, N. Y.
Schmidt, J. J., Bendix Aviation Corp., Red Bank, N. J.
Shaw, A. G., Ebasco Services Inc., New York, N. Y.
Smith, C. B., D.P.S. Corp., New York, N. Y.
Smith, C. S., Teterboro Airport, Teterboro, N. J.
Smith, T., U. S. Army Signal Corps., Ft. Monmouth, N. J.
Sulaiman, K. M. A. M., Polytechnic Inst., Brooklyn, N. Y.
Treece, B. G., Ebasco Services, Inc., New York, N. Y.
Weindling, J. I., C.C.N.Y., New York, N. Y.
Weisler, A. B., Albert Pipe Supply, Brooklyn, N. Y.
Westberg, R. W., Bell Tel. Labs., Inc., New York, N. Y.
Wiesner, O. I., (Student), Pratt Inst., Brooklyn, N. Y.
Weissman, S., New York Univ., New York, N. Y.
Wilgus, W. H., Sperry Gyroscope Co., Great Neck, N. Y.
Wilkins, R. D., Grumman Aircraft Engg. Corp., Bethpage, L. I., N. Y.

4. Southern

Andrews, J. E., La. Power & Light Co., Gretna, La.
Blythe, K., Carolina Aluminum Co., Calderwood, Tenn.
Bowers, T. N., T.V.A., Chattanooga, Tenn.
Bowling, W. L., U.S. Waterways Experiment Station, Vicksburg, Miss.
Braidwood, D. W., Schlumberger Well Survey Corp., New Orleans, La.
Brown, H. R., Mississippi Power Co., Gulfport, Miss.
Broughton, W. J., Jr., Appleton Elec. Co., Birmingham, Ala.
Caboche, L. E., Louisiana Power & Light Co., Gretna, La.
Campbell, I. S. (re-election) North Carolina State College, Raleigh, N. C.
Cockrum, H. B., Knoxville Utilities Board, Knoxville, Tenn.
Crochet, C. L., Cities Service Refining Corp., Butadiene Plant, Lake Charles, La.
Crockett, C. K., Hollinsworth & Whitney, Mobile, Ala.
Davis, H. W., Esso Standard Oil Co., Charlotte, N. C.
Eggart, G. J., Jr., Southern Bell Tel. Co., Pensacola, Fla.
Glass, H. C., Western Union Tel. Co., Atlanta, Ga.
Guy, L. E., Electronic Engg. Co., Norfolk, Va.
Hartman, H. C., Jr., Nashville Elec. Service, Nashville, Tenn.
Harvey, R. R., Reynolds, Smith & Hills, Jacksonville, Fla.
Hill, H. C., Georgia Power Co., Atlanta, Ga.
Howe, A. L., Aluminum Co., Badin, N. C.
Hudgins, E. S., T.V.A., Wilson Dam, Ala.
Hungerford, W. M., La. Pl. & El. Co., Baton Rouge, La.
Ivey, J. W., J. Frank Blakely Co., Spartanburg, S. C.
Jonakin, S. N., Jr., T.V.A., Chattanooga, Tenn.
Lanier, H. H., Southern Bell Tel. & Tel. Co., Birmingham, Ala.
Lehmann, H. E., Louisiana Power & Light Co., New Orleans, La.
Lines, C. W., Georgia Power Co., Atlanta, Ga.
Lowman, B. L., South Carolina Elec. & Gas Co., Columbia, S. C.
Nason, W. L., T.V.A., Chattanooga, Tenn.
Pavich, M. O., Dept. of the Army, Arlington, Va.
Pittman, L., Aluminum Co. of America, Alcoa, Tenn.
Puckett, P. J., Westinghouse Elec. Corp., Roanoke, Va.
Ratcliff, W. L., W. L. Ratcliff Co., Shreveport, La.
Reed, D. B., Virginia Theological Seminary, Alexandria, Va.
Reynolds, J. J., III., Western Union Tel. Co., Atlanta, Ga.
Ruble, G. B., Renolds, Smith & Hills, Jacksonville, Fla.
Smith, W. F., Jr., United Clay Mines Corp., Sandersville, Ga.
Smith, W. R., Western Union Tel. Co., Atlanta, Ga.
Taylor, J. W., S. C. Elec. & Gas Co., Columbia, S. C.
Teal, B., Carolina Tel. & Tel. Co., Tarboro, N. C.
Thompson, T. W., Alabama Power Co., Birmingham, Ala.
Tribbie, W. B., Pacific Tel. & Tel. Co., Sacramento, Calif.

5. Great Lakes

Bangert, D. G., Standard Oil Co., Wood River, Ill.
Becker, J. W., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Beckwith, D. J., Dow Chemical Co., Midland, Mich.
Bridge, W. A., Dow Chemical Co., Midland, Mich.
Brooks, R. W., Barber Colman Co., Rockford, Ill.
Browde, A., Farnsworth Television & Radio Corp., Ft. Wayne, Ind.
Cahn, S. L., Askania Regulator Co., Chicago, Ill.
Camburn, R. D., Commonwealth & Southern Corp., Jackson, Mich.
Carter, M. R., Underwriters' Labs., Inc., Chicago, Ill.
Cassidy, F. M., Micro Switch, Freeport, Ill.
Congreve, G., International Harvestor Co., Chicago, Ill.
Cunningham, F. V., Line Material Co., So. Milwaukee, Wis.
Dudhane, L. B., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Everett, J. W., Sr., Duncan Elec. Mfg. Co., Lafayette, Ind.
Gamburd, B. B., Public Lighting Comm., Detroit, Mich.
Jaqua, B. G., Scott-Jaqua Co., Indianapolis, Ind.
Johnson, R. V., General Elec. Co., Chicago, Ill.
Kroon, J. M., Corning Glass Works, Chicago, Ill.
Kuehl, E. M., Wisconsin Elec. Power Co., Milwaukee, Wis.
Lammers, L. W., Allen-Bradley Co., Milwaukee, Wis.
Landman, R. M., Commonwealth & Southern Corp., Jackson, Mich.
Liepold, R. B., Automatic Elec. Co., Chicago, Ill.
Lindgren, A. R., Jr., F. L. Cusac & Assoc. Inc., Chicago, Ill.
Miller, E. W., Jr., Control Corp., Minneapolis, Minn.
Morse, W. R., General Motors Corp., Pontiac, Mich.
Morrison, R. J., Public Service Co. of No. Ill., Oak Park, Ill.
Nelson, J. A., Commonwealth & Southern Corp., Jackson, Mich.
Putz, C., Peoples Gas, Light & Coke Co., Chicago, Ill.
Quarstrom, E., Barnes & Reinecke, Chicago, Ill.
Raubach, G. T., Harnischfeger Corp., Milwaukee, Wis.
Raymond, F. W., Illinois Bell Tel. Co., Peoria, Ill.
Ryerson, R. A., Bell Tel. Co., Davenport, Iowa
Rynnstrom, L., Univ. of Minnesota, Minneapolis, Minn.
Saven, N. I., General Elec. Co., Chicago, Ill.
Schatz, E., Sargent & Lundy, Chicago, Ill.
Schoemer, R. G., Kohler Co., Kohler, Wis.
Schuh, E., Bureau of Reclamation, Bismarck, N. D.
Schumann, H. W., Precise Products Co., Racine, Wis.
Sickel, C. T., Minnesota Power & Light Co., Duluth, Minn.
Slothower, J. C., Univ. of Minnesota, Minneapolis, Minn.
Weber, L. C., Iowa Public Service Co., Sioux City, Iowa
Wolf, G. T., Rose Polytechnic Inst., Terre Haute, Ind.
Ziehr, D. J., Allis-Chalmers Mfg. Co., Milwaukee, Wis.

6. North Central

Asbridge, R. D., Bureau of Reclamation, Casper, Wyo.
Chambers, W. R., Omaha Public Power Dist., Omaha, Neb.
Richardson, R. J. (Student), Univ. of Colorado, Boulder, Colo.
Smith, W. L., Joe Smith Machinery, Denver, Colo.
Warner, D. F., Western Geophysical Co., Cheyenne, Wyo.

7. South West

Barracano, H. R., Public Service Co. of Oklahoma, Tulsa, Okla.
Catt, D. W., El Paso Natural Gas Co., El Paso, Tex.
Carson, R. N., Jr. (re-election), Southwestern Bell Tel. Co., Houston, Tex.
Chamblee, J. F., Texas Power & Light Co., Dallas, Tex.
Crow, C. J., Fagan Elec. Co., Little Rock, Ark.
Drew, H. R., Texas Elec. Service Co., Ft. Worth, Tex.
Frank, H. R., Continental Oil Co., Ponca City, Okla.
Fuller, W. F., Jr., Texas Elec. Service Co., Ft. Worth, Tex.
Glenn, B. (re-election), Southwestern Bell Tel. Co., Tulsa, Okla.
Griffin, H. C., Jr., Southwestern Public Service Co., Clovis, N. Mex.
Gunn, Cy., Southwestern Bell Tel. Co., Houston, Tex.
Harvey, E. P., Public Service Co. of New Mexico, Albuquerque, N. Mex.
Heyer, C. E., I.B.M. Corp., Kansas City, Mo.
Helgeson, V. L., Emerson Elec. Mfg. Co., St. Louis, Mo.
Johnson, D. L., Oklahoma A. & M. College, Stillwater, Okla.
Kaplan, A., The Emerson Elec. Mfg. Co., St. Louis, Mo.
Knaus, R. G., General Elec. Co., St. Louis, Mo.
Krueger, R. E., Los Alamos Scientific Lab., Los Alamos, N. Mex.
Kurio, N. A., Lower Colorado River Authority, Austin, Tex.
Lerner, I. S., Continental Oil Co., Ponca City, Okla.
Lindsay, W. J., Humble Oil & Refining Co., Houston, Tex.
Loewen, B. F., Phillips Petroleum Co., Bartlesville, Okla.
Mean, W. A., Continental Oil Co., Ponca City, Okla.
Miller, O. M., Southwestern Public Service Co., Plainview, Tex.
Montgomery, F., Jr., Texas Elec. Service Co., Sweetwater, Tex.
Morgan, W. H., Houston Lighting & Power Co., Houston, Tex.
Newton, K. E., Consolidated Vultee Aircraft Corp., Daingerfield, Tex.
Owen, R. K., Southwestern Public Service Co., Plainview, Tex.
Pappas, T. H., 5427 Tremont St., Dallas, Tex.
Pittier, V. M., Black & Veatch, Kansas City, Mo.
Richards, S. M., Texas Gulf Sulphur Co., Newgulf, Tex.
Ross, D. A., Stanolind Pipe Line Co., Tulsa, Okla.
Rutledge, C. C. (Student), University of Texas, Austin, Tex.
Serenco, H., U.S. Army Corps of Engineers, St. Louis, Mo.
Serkland, F. K., Bureau of Reclamation, Amarillo, Tex.
Sprangel, V. M., Public Service Co. of Oklahoma, Tulsa, Okla.
Thompson, C. G., American Tel. & Tel. Co., Dallas, Tex.
Van Duyne, G. G., Southwestern Bell Tel. Co., Tulsa, Okla.
Van Horn, J. E., Southwestern Bell Tel. Co., Tulsa, Okla.
VanHoozer, C. H., Phillips Petroleum Co., Bartlesville, Okla.
Wier, S. L., Southwestern Public Service, Plainview, Tex.
Yeakley, J. E., Texas Power & Light Co., Dallas, Tex.
Zwaska, L. G., General Elec. Co., Dallas, Tex.

8. Pacific

Atha, F. P., Jr., Douglas Aircraft Co., Inc., El Segundo, Calif.
Berger, M., Lockheed Aircraft Corp., Burbank, Calif.
Bishop, A. F., Pacific Gas & Elec. Co., Oakland, Calif.
Bromley, W. W., Dept. of Water & Power, Boulder City, Nev.
Downing, W. F., Fluor Corp. Ltd., Los Angeles, Calif.
Greif, H. D., Public Utilities Comm., San Francisco, Calif.
Heard, G. E., Southern California Water Co., Los Angeles, Calif.
Hixson, E. L., U.S. Naval Electronics Lab., San Diego, Calif.
Kearney, P. S., Wesix Elec. Heater Co., San Francisco, Calif.
King, A. B., Jr., General Elec. Co., Los Angeles, Calif.
Kitchens, J., Pacific Gas & Elec. Co., San Francisco, Calif.
Maine, H. R., Arabian American Oil Co., San Francisco, Calif.
Morris, J. E. D., Westinghouse Elec. Corp., Huntington Park, Calif.
Overton, G. P., Pacific Gas & Elec. Co., San Francisco, Calif.
Parker, N. F., North American Aviation, Downey, Calif.
Payne, V., Jr., Pacific Tel. & Tel. Co., Los Angeles, Calif.
Robbins, P. M., North American Aviation, Inc., Los Angeles, Calif.
Stern, R. C., City & County of San Francisco, San Francisco, Calif.
Tribble, D. D., U.S. Bureau of Reclamation, Sacramento, Calif.
Williams, H. M., California Elec. Power Co., Riverside, Calif.

9. North West

Dodd, L. S., The Alaska Railroad, Seattle, Wash.
Emslie, C. M., Dept. of Lighting, Seattle, Wash.
Gomulkiewicz, P., Aluminum Co. of America, Vancouver, Wash.
Harrison, L. E., Civil Aeronautics Adm., Seattle, Wash.
Laughlin, J. W., Oregon State College, Corvallis, Oreg.
Noren, D. V., U.S. Bureau of Reclamation, Coulee Dam, Wash.
Richardson, E. L., Bonneville Power Admin., Portland, Oreg.
Rose, C. E., U.S. Bureau of Reclamation, Billings, Mont.
Sagendorph, P. M., Newbery Neon Elec. Co., Richland, Wash.
Stephenson, A. W., Reynolds Metals Co., Troutdale, Oreg.
Tanner, S. M., Puget Sound Power & Light Co., Seattle, Wash.

10. Canada

Anderson, K. G., Canadian General Elec. Co., Toronto, Ontario, Canada
Baker, J. E. P., Northern Elec. Co., Montreal, Quebec, Canada
Boyd, R. A., Hydro-Quebec, Montreal, Quebec, Canada
Brooks, R. F., Shawinigan Water & Power Co., Shawinigan Falls, Quebec, Canada
Burnett, R. S., Canadian Niagara Power Co., Niagara Falls, Ontario, Canada
Busby, C. H., Aluminum Co. of Canada, Shipshaw, Quebec, Canada
Chevrette, A., Shawinigan Water & Power Co., Three Rivers, Quebec, Canada
Crosby, W. H., Bepco Canada Ltd., Montreal, Quebec, Canada
Hale, N. E., English Elec. Co. of Canada, Ltd., St. Catharines, Ontario, Canada
Haney, D. F., Canadian Pacific Railway Co., Montreal, Quebec, Canada
Howard, D. W., English Elec. Co. of Canada, Ltd., St. Catharines, Ontario, Canada
Kisick, R. F., Hydro-Elec. Power Comm. of Ontario, Toronto, Ontario, Canada
Newton, D. L., Hydro Elec. Power Comm. of Ontario, Queenston, Ontario, Canada
Roy, F., The Shaw Water & Power Co., Shawinigan Falls, Quebec, Canada
Ryan, W. J. (re-election), Hydro Elec. Power Comm. of Ontario, Queenston, Ontario, Canada
Shute, V. D., Hydro Elec. Power Comm. of Ont., Niagara Falls, Ontario, Canada
Sturton, A. B., Shawinigan Water & Power Co., Shawinigan Falls, Quebec, Canada
Thibault, S., Shawinigan Water & Power Co., Montreal, Quebec, Canada

Elsewhere

Bhattacharya, P. K., Marshall Sons & Co., Ltd., Gainsboro, England
Guha, R. C., Govt. of West Bengal, Calcutta, India
Nadler, M., Tesla n.p. Vyzkum, Prague, Czechoslovakia
Nambudripad, D. K., College of Engineering, Madras, S. India
Rishi, S. K., A. C. Cossor Ltd., London, England
Waheed, K. M., % Riaz Art Studio, Rawilpindi, Pakistan

Total to grade of Associate

United States and Canada, 357
Elsewhere, 6

OF CURRENT INTEREST

Electrical Manufacturers Reach All-time Production, Sales Peak

The electrical manufacturing industry repeated its record-breaking performance of 1947 by establishing a new over-all peacetime peak in production and sales in the year just past. Total production is estimated at 7¹/₂ billion dollars, 65 per cent higher than the prewar peak in 1941, and 275 per cent higher than in 1939, according to W. J. Donald, managing director, National Electrical Manufacturers Association.

The postwar surge in demand for electrical service has created an unusual demand for most of the products of the electrical manufacturer; higher, compared with prewar, than the demand for durable goods generally. This surge is world-wide and applies not only to the United States, but also to Canada, Great Britain, Western Europe, and China. Not the least of the influences at work is the recognition of cost reducing values of industrial equipment and the power it utilizes.

The long-range expansion program of the American electrical utilities and the high activity in residential, industrial, commercial, and public construction promise to continue the high level of business for the entire industry through 1949, and probably for several years to come. This does not mean that high production will exist in all segments of the industry equally. It is possible that manufacturers in certain product categories will decrease production, while others will increase or else remain stationary.

For the second successive year, electric appliances accounted for a very large proportion of the total production of the electrical manufacturing industry. Sales of all types of appliances amounted to 1³/₄ billion dollars. During 1948, 5,000,000 refrigerators were sold, more than 1,500,000 over the previous peak year. Also sold were 750,000 freezer units, a product with negligible sales in the prewar era.

Sales of electric ranges exceeded the 1947 peak by well over half a million, with the increase in unit sales in 1948 exceeded the total number sold in 1940. The total was about 1,700,000 for ranges of the electric type.

Other appliances which show a marked increase in production and sales include washing machines, toasters, roasters, flat irons, and coffee makers. Only one major appliance did not show a gain, the electric storage water heater. In 1949, it is expected that supply of all appliances will match demand, a condition which has been expected since the end of 1947.

Electrical supplies for construction, including such items as wiring devices, fuses, small air circuit breakers, knife switches, panelboards, and so forth, were in considerable demand, and sales reached a new high with total business up five per cent over 1947, up 80 per cent over 1941, and 250 per cent greater than in 1939. The past year's sales were mostly in material for use in residential construction, but it is expected that, as residential units begin to meet demand, the trend will be toward manufacture for commercial and industrial use.

A diminishing rate of increase is noted in the industrial field on the total sale of such items as motors and generators, welding equipment, industrial controls, heating units, and other such devices. The small gain over 1947 figures was due mainly to increased activities in some lines which offset decreases in other categories.

One of the largest of all groups to expand within the industry was that segment which produces equipment used for generation, transmission, and distribution. Sales here were one-third greater than in 1947 and four times that of 1939. Paralleling this group exactly was the increase in the demand for watt-hour and demand meters.

The over-all trend seems to indicate that considerable progress has been made to fill the void created by the war, and that postwar demands for electrical goods are being filled rapidly. However, the expansion of transmission and distribution facilities are expected to create a new demand for those products which utilize electricity.

Edison Recreates Invention

To help celebrate the birthday of Thomas Alva Edison on February 11, 1949, the Edison Birthday Committee is reissuing this photograph of Edison recreating the invention of the incandescent lamp upon the 50th anniversary of its invention on October 21, 1879. Looking on are Henry Ford, automobile magnate, and Francis Jehl

Committee Asks Edison's Birthday to Be Holiday

The Edison's Birthday Committee, in collaboration with the Thomas Alva Edison Foundation, is directing plans for the annual national observance of February 11, the inventor's birthday, as Edison Day.

The emphasis of this program is placed upon community recognition of Edison's contributions to the scientific and industrial progress of the community and of the United States as a whole. Service clubs throughout the country have indicated their interest in planning special Edison Day programs—these include Rotary, Lions, Kiwanis, and Civitan. The United States Chamber of Commerce plans to advise local chambers of the opportunity to participate in Edison Day.

A number of interested industries and businesses are planning special advertising and public relations tie-ins. Several of them plan to use an Edison theme in their plant city community relations campaigns while others will have open house for the community. Radio also will play an important part in the observance; the February 7 "Voice of Firestone" program will be an Edison tribute and several other national network programs are planning to participate in observing Edison Day. Local radio will be represented by the programs of utility companies.

Governors have been asked to proclaim February 11 as Edison Day in their states. The mayors of the various towns with a special interest in Edison also will be asked to proclaim Edison Day. Any other interested groups may obtain an Edison biography, suggested text for a speech, a community planning guide, a service club program guide, and an Edison chronology from the Edison's Birthday Committee, 10 Downing Street, New York 14, N. Y.

RMA Submits Plan for Nation-wide Television

Plans for future national television service, continuing and expanding present standard (very high) frequencies for larger cities and proposing future supplementary broadcasting and television receivers for smaller cities in the higher (ultrahigh) frequencies, were submitted yesterday to the Federal Communications Commission by a committee of the Radio Manufacturers Association. The manufacturers' plan would avoid obsolescence for the public of current television receivers and largely avoid costly future "2-band" sets. Also, the FCC was urged to end its temporary "freeze" on new television station construction permits, as quickly as possible, to allow maximum development in 1949 of the current standard television broadcasting and receivers.

The RMA plan contemplates that the present standard very-high-frequency television system shall be the "backbone" of national television service principally for larger cities and shall be expanded at once to maximum use; also that the higher ultrahigh frequencies be allocated promptly for use, within two or three years, generally for television service in the smaller cities, with a minimum of overlapping of the higher and lower frequency systems and, therefore, a minimum of 2-band receivers. In the meanwhile, for both small and large cities it is proposed to use the present very high frequencies for maximum service and stations. The RMA proposals would provide at least four television stations in each city, for competition and network service. The commission was urged to end its present "freeze" on the new very-high-frequency stations as soon as possible and before specifically allocating the future ultrahigh-frequency service. It would be from one to three years before the supplementary ultrahigh-frequency service, transmitters and sets, would be available for the smaller cities.

Westinghouse to Make Ship Nuclear Reactor

The Chicago Operations Office of the United States Atomic Energy Commission has announced that a letter contract has been entered into with the Westinghouse Electric Corporation of Pittsburgh, Pa., for the construction of an experimental nuclear reactor to meet specifications for eventual use for ship propulsion. Final terms of the contract will be negotiated at a later date. Work under the contract will be carried on in co-operation with the Argonne National Laboratory, major center of the commission's reactor development program. The objective of the developmental project is to meet requirements provided by the United States Navy Department Bureau of Ships for the propulsion of naval vessels.

Under the terms of this allocation, the responsibility for the design, development, and engineering of the new reactor rests with the Argonne Laboratory. The Westinghouse Company has been delegated responsibility for the detailed engineering, construction, and operation of the reactor, and will undertake such research and development activity as may be assigned to it by the commission.

The Westinghouse Corporation has had extensive experience in atomic energy work, having made a substantial contribution to the wartime program of the Manhattan Engineer District in the processing of uranium and the manufacture of specialized equipment for use in the U-235 separation plant at Oak Ridge, Tenn. Westinghouse scientists also have taken an active part in other research programs of the AEC.

Television Extended by New RCA Method

First practical use of a newly developed method of extending television coverage by reducing interference between stations on the same channel is under way on a full-time basis between the New York and Washington, D. C., television stations of the National Broadcasting Company. The new method, known as television carrier synchronization, has been in regular operation since early in December, 1948, employing facilities at the Radio Corporation of America Laboratories, Princeton, N. J.

The immediate effect of these operations has been to extend interference-free service to thousands of additional viewing families in the "fringe," or outlying service areas, of television stations *WNBT*, New York, and *WNBW*, Washington. These operations point the way to application of synchronization to stations in other parts of the country where the co-channel interference has become a problem.

Use of synchronization permits a closer spacing of television stations on the same channel than is possible without this method of reducing interference between stations. It also enlarges the service area of television stations, thus enabling television to serve many more people than otherwise could be served. This is of particular importance to rural sections since it makes possible service to such sections which could not be obtained otherwise.

Canadian Board Picks Hackbusch. The Canadian Radio Technical Planning Board has elected Ralph Hackbusch, vice-president and general manager of Stromberg-Carlson Ltd., Toronto, Ontario, Canada, as its president. An electrical engineer, Hackbusch headed the radio division of Research Enterprises Ltd. when that body was organized as a government-owned industry in 1940 to undertake the research and manufacture of radio, optical glass, and other material essential to the war effort. The board which he now will head is responsible for allocating frequencies on Canadian broadcast channels, and also aids in correcting interference problems which result from the jamming of too many stations near the same frequencies.

Journal Names Advisory Board. The new scientific and engineering magazine of the southeastern United States, *The Journal of Southeastern Research*, has announced that the following 14 southeastern scientists will serve as members of its advisory board: Dean O. V. Adams, Texas Technological College; Doctor Luis H. Bartlett, director of the engineering experiment station, Louisiana State University; Doctor J. W. Beams, chairman, physics department, University of Virginia; Dean George W. Branigan, University of Arkansas; Doctor J. H. Coulliette, director, Industrial Research Institute, University of Chattancoga; Dean Paul M. Gross, Duke University; Doctor Albert H. Holland, Jr., director of research and medicine, Oak Ridge National Laboratory; Dean Roger P. McCutcheon, Tulane University; Doctor E. B. Norris, director of the engineering experiment station, Virginia Polytechnic Institute; Doctor J. Stanton Pierce, head of the chemistry department, University of Richmond; Doctor W. G. Pollard, director, Oak Ridge Institute for Nuclear Studies; Doctor Herman M. Roth, chief of the physics research division, Oak Ridge National Laboratory; Doctor Walter M. Scott, director, United States Department of Agriculture Southern Regional Research Laboratory; and Doctor W. G. Van Note, director of the engineering experiment station, North Carolina State College. Details of this new journal were given on page 84, the January 1949 issue of *ELECTRICAL ENGINEERING*.

Electric Motor Plant Opened by GE. A $3,000,000 motor manufacturing plant, which at peak production will be able to turn out more than 1,500 electric motors weekly, was opened officially by the General Electric Company at San Jose, Calif., November 18, 1948. Situated on a 57-acre tract, this plant ultimately will produce all of the company's single-phase capacitor integral motors designed for operation on 115- or 230-volt circuits. It is equipped also to produce 5- to 500-horsepower polyphase motors designed for use with irrigation pumps. Approximately 100 per cent of the plant's polyphase motor production will be for the western market, while about 90 per cent of the small motors will go to national and international markets. The San Jose plant has been operating since last fall and should reach peak production early in 1949.

Brunetti Joins Stanford Research Institute. Doctor Cledo Brunetti, formerly chief of the engineering electronics section of the National Bureau of Standards, has joined the staff of the Stanford Research Institute, Palo Alto, Calif. He will be concerned principally with the development of electronics in the West. Brunetti is known internationally for his work in miniature radio equipment and toward the development of printed electric circuits for miniature electronic equipment. The 1941 recipient of the Eta Kappa Nu Award as the Outstanding Young Electrical Engineer, he is the author of more than 30 technical publications, as well as textbooks and technical reports. Brunetti's memberships include the

Turbine Plant Nears Completion

Shown are workmen installing one of 51 traveling cranes to be used in the nearly completed, $30,000,000, 20-acre turbine manufacturing plant of the General Electric Company, Schenectady, N. Y. Under construction for the past two years, the plant will be producing turbines and generators ranging from 20,000 kw to 200,000 kw in 1949, and, with 5,000 employees, will be the largest turbine manufacturing facility in the world

---

Institute of Radio Engineers, and the honorary technical societies of Sigma Xi, Tau Beta Pi, Eta Kappa Nu, and Pi Tau Pi Sigma.

NBS Names New Additions. The National Bureau of Standards has announced the addition of three scientists to positions with the bureau. William A. Wildhack, associate editor of the *Review of Scientific Instruments* and chairman of the committee on scientific equipment of the National Research Council, has been named the chief of the missile instrumentation section, where he will be responsible for the direction of flight tests of guided missiles and the development of equipment for evaluating their performance. Doctor Curtis J. Humphreys, with the bureau since 1928 as a specialist in spectroscopy and the observation and theoretical interpretation of spectra of noble gases and precise interferometric measurements of wave lengths for standards, will be the chief of the radiometry section of the atomic and molecular physics division. He will be concerned with standards and constants of radiant energy, analysis of infrared and ultraviolet absorption and emission spectra, line emission spectra and flame spectra in the infrared, and the utilization of photoconducting detectors in the high-resolution spectroscopy. Doctor Chester H. Page, formerly chief of the electronic computor section, has been named as electronics consultant to the bureau and will be available to all divisions concerned with electronic research. He also will participate in over-all research projects of the electronics division, including research and development of new types of electronic ordnance devices, electronic tubes, circuits, and controls, and high-speed digital computing machines.

"Structure of Matter" Series Announced. John Wiley and Sons, New York, N. Y., will begin a series of advanced monographs in 1949 on the structure of matter to be written by outstanding contributors in specialized fields. The first book, published January 3, 1949, was called "The Structure of Matter," and summarized the results of modern theories on the subject, plus a review of the scope of the phenomena explained by quantum mechanics. The authors were F. O. Rice and Edward Teller, professors of chemistry and physics respectively.

Director, Assistant, Named by MRI. Officers of the Midwest Research Institute, Kansas City, Mo., have announced the appointment of Doctor G. E. Ziegler, specialist in X-ray diffraction studies, as director, and Doctor C. O. Dohrenwend, former director of the mechanics department, Illinois Institute of Technology, as assistant director. Doctor Ziegler, now acting as chief administrator for the institute, joined that organization as executive scientist at its inception in 1945. Doctor Dohrenwend has been research consultant at the institute since 1946.

Carnegie Book Fund Complete. The Carnegie Institute of Technology, Pittsburgh, Pa., has announced the completion of its $110,000 book fund drive with the receipt of a $35,000 grant from the Buhl Foundation of Pittsburgh. The institute will spend about $75,000 for engineering and science publications, $25,000 for material on the fine arts, and $10,000 for the women's college of Carnegie Institute. The institute also announced the reopening of its $4,000,000 building and renovation program, including the erection of a power plant, steam and electricity distribution system, and a $1,000,000 wing to the Engineering Hall, plus the redesigning of existing facilities.

RESEARCH • • • • • •

Fellowships Offered by National Research Council

The Fellowship Office of the National Research Council, Washington, D. C., announces that applications for fellowships in the natural sciences now are being accepted for consideration at the spring meetings of the Fellowship Boards. The fellowship programs are supported by the Rockefeller Foundation, the Radio Corporation of America, Merck and Company, the Carnegie Corporation, and the Atomic Energy Commission, and administered by the National Research Council. These provide for both predoctoral and postdoctoral research by United States citizens (in one case, Canadian citizens are eligible). Fellowship work may be pursued in the physical, biological, agricultural, and basic medical sciences, including engineering, anthropology, and psychology. One program provides special training in the social sciences for persons with doctorates in the natural sciences, or training in the natural sciences for persons with doctorates in the social sciences.

The basic stipends for the predoctoral fellowships range from $1,500 to $2,400 per year; the basic stipends for the postdoctoral fellowships range from $2,500 to $5,000 per year. The stipend in each case will be determined by the appropriate board, with consideration given to the amount of training, marital status, number of dependents, and so forth. All programs provide for necessary tuition and fees in addition to the stipend.

A Fellow must be a citizen of the United States and under 35 years of age at the time of appointment. He or she must have had training in some branch of the biological or physical sciences equivalent to that represented by the doctor of philosophy or doctor of science degree and must have demonstrated superior ability for research.

Fellowships in the four programs will be awarded by the AEC Fellowship Boards at meetings to be held in March 1949. Applications to be considered at these meetings must be filed before February 15, 1949. Applications and all required papers should be submitted during the month of January 1949. For application blanks and full information, address the Fellowship Office, National Research Council, 2101 Constitution Avenue, Washington 25, D. C.

Two Jet Centers Established. Two centers for research on rocket and jet propulsion have been established under a $500,000 appropria-

tion from the Daniel and Florence Guggenheim Foundation. Under the terms of the grant, the money will be used to pay for professorial salaries, graduate student stipends, and similar expenses for the next seven years, with buildings and equipment being provided by Princeton University, N. J., and the California Institute of Technology, Pasadena, Calif., the sites of the centers. The new institutions will provide postgraduate education and research in jet propulsion and rocket engineering, but will stress the peacetime uses of rockets and jet propulsion.

New GE Measurement Laboratory. An ultramodern 5-story brick and steel building, which will house the most completely equipped electrical measurements laboratory in the world, will be erected by the General Electric Company's meter and instrument divisions at Lynn, Mass. The structure will provide excellent facilities for research and development in the field of electrical measurements and permit greater co-ordination between laboratory and engineering personnel now located in six different Lynn buildings, and will include offices, exhibit rooms, and customer meeting rooms for administrative and sales personnel. Official groundbreaking ceremonies were held December 29, 1948, not far from where the parent company of General Electric, the Thomas-Houston Company, was formed in 1883. Scheduled for completion late in 1949, it was designed by J. Gordon Turnbull, Inc., of St. Louis, Mo., and will be built by the Thompson-Starrett Company of New York, N. Y.

GE Finishing New Research Laboratory. The new research laboratory of the General Electric Company, Schenectady, N. Y., is nearing completion, it was announced by a company official at the formal opening in December 1948 of the first section of the building. Situated in nearby Niskayuna, N. Y., the total cost of the building is estimated at about $18,000,000. Expected to be ready for use in 1950, the formal dedication will be combined with the 50th anniversary celebration of the founding of the laboratory in 1900 by Doctor Willis R. Whitney. The new structure includes a main laboratory building, as well as separate laboratories for research in low-temperature and high-energy radiations, a chemical pilot plant, and a steam generation plant.

EDUCATION . . . .

East's Engineering Educators Meet at Drexel Institute

Deans and professors from 21 eastern colleges and universities met at the Drexel Institute of Technology, Philadelphia, Pa., for the Middle Atlantic section meeting of the American Society for Engineering Education on December 11, 1948. Together with the 400 delegates, leading industrial and government representatives attended.

Conferences and panel meetings were held to discuss the educational problems of electrical, chemical, civil, and mechanical engineering, and also physics and mathematics. A general session of all members was held in which the over-all picture of American engineering educational standards and systems were debated by leading figures in both instructorial and professional positions.

The international situation and its tie-in with technological advances in all nations was stressed, and it was suggested that professional men could very well be used as good-will ambassadors because of the mutual high level of understanding between technical men regardless of nationality.

Illinois Tech Announces Graduate Study Deadline

Applications for fellowships, scholarships, and assistantships for graduate study, research, and teaching at Illinois Institute of Technology, Chicago, Ill., will be accepted until March 15, 1949, it has been announced. Fellowships are available in special fields of study—power systems engineering, gas technology, and industrial research. Scholarships covering tuition are available for exceptional students.

Teaching assistantships are open in all departments. Half-time assistants may take a half-time graduate program and third-time assistants a three-quarter-time study program, with the remainder in each case devoted to teaching. Stipend for half-time assistants is $1,314, from which $275 tuition is payable. For third-time assistants the stipend is $876, from which $412.50 tuition is payable.

Graduate courses leading to master's and doctor's degrees are offered in architecture, bacteriology, biochemistry, biology, business and economics, business and engineering administration, chemical engineering, chemistry, city planning, civil engineering, electrical engineering, mathematics, mechanical engineering, mechanics, metallurgical engineering, physics, psychology, public administration, and public engineering administration. Applications should be addressed to the Examiner of Credentials, Graduate School, Illinois Institute of Technology, Technology Center, Chicago 16, Ill.

Candidates Being Accepted for Westinghouse Fellowship

The Illinois Institute of Technology, Chicago, Ill., is accepting applications for the 1949 Westinghouse fellowship in power systems engineering, it has been announced. An award of $1,500 and free tuition for three semesters of full-time intensive training leading to a master of science degree in electrical engineering will be made to the successful applicant.

Candidates must have a bachelor's degree in electrical engineering from an accredited engineering college. The award will be based upon personal qualifications, interest, and scholarship. The course of study includes both practical and theoretical training. It includes experience with the $90,000 a-c network calculator used in actual systems studies for utility and manufacturing companies.

A research project in power systems engineering is determined through consultation with central station engineers of the Westinghouse Electric Corporation. Term of the fellowship will begin September 13, 1949. Further information and application blanks may be obtained from Dean W. A. Lewis, Illinois Institute of Technology, Technology Center, Chicago 16, Ill.

New York to Hear Design Lecture Series

A series of eight lectures in industrial electronics design will be offered in New York, N. Y., beginning February 1, 1949, and will be held on subsequent Tuesdays and Thurs-

ASEE Electrical Engineering Panel

Reading left to right, the following educators constituted the electrical engineering panel at the Middle Atlantic section meeting of the American Society for Engineering Education held at the Drexel Institute of Technology, Philadelphia, Pa.: Professors E. O. Lange (A '18) of the Drexel Institute, H. M. Jenkins (M '46) of Swarthmore College, S. Reid Warren (M '41) of the University of Pennsylvania, L. V. Bewley (A '27, F '47) of Lehigh University, and Morland King (A '06, F '25) of Lafayette College

days until completed. These lectures, compiled and planned by prominent electronic engineers from leading industrial concerns, will be held in the Tower Lounge of the Park Central Hotel, 7th Avenue and 55th Street.

Each of the contributing engineers will lecture in the field of his specialization and will be based on actual experience. All material will be co-ordinated to give a complete analysis of design methods in the application of electronics to industrial problems. Fee for the first series of eight lectures will be $25, which includes all materials necessary for the registrant plus a workbook containing an expanded outline of the material to be covered.

The first series will be on "The Design of Dielectric Heating Equipment," and will include design of equipment to satisfy commercial dielectric heating requirements, evaluation of performance, production operation, design of conventional generators and associated power supply units, and the selection of appropriate commercial equipment for dielectric heating applications. For full details of the program, interested persons should write or call the School of Industrial Technology, 149 East 26th Street, New York, N. Y.

OTHER SOCIETIES • • •

"What's New" Theme for 1949 Chicago Conference

Plans already well under way for the 1949 Chicago Technical Conference and Production Show at the Hotel Stevens March 14–17, 1949, call for a "What's New" theme. Since the conference and production show are sponsored by the 55 affiliated societies making up the Chicago Technical Societies Council, the "What's New" theme will cover a wide range of subjects such as equipment, methods, materials, shop practice, processing, management, research, plant facilities, and so forth.

The conference, over the 4-day period, will be broken up into 17 sessions with a maximum of three sessions at any one time. Approximately 50 nationally known speakers will bring their latest thinking and experience to the many subjects to be considered. Program details are being worked out so that the subjects will be of interest to the supervisory personnel of industry as well as to the members of the 55 affiliated societies.

The Chicago Production Show is making great progress also. As of December 15 more than half of the total space in the Hotel Stevens Exhibition Hall had been reserved by manufacturers, and it is expected that all the space will be taken. Since the Production Show will parallel the interests of the conference it will carry the same general theme of "What's New." Exhibitors will show the latest in equipment, materials, methods, and services that will help maintain American world-wide industrial supremacy. No registration fee of any kind will be required for the Production Show. All that is needed is the filling out of a simple form giving company connection and type of work in order to be admitted. Present plans for the conference call for a nominal registration fee of $1 for the 4-day session, provided registration is made prior to March 10.

Future Meetings of Other Societies

American Chemical Society. Semiannual meeting. March 28–April 1, 1949, San Francisco, Calif.

American Society of Chemical Engineers. Los Angeles, Calif., regional meeting, March 6–9, 1949; Tulsa, Okla., regional meeting, April 8–12, 1949.

American Institute of Mining and Metallurgical Engineers. Annual meeting. February 14–17, 1949, Fairmont Hotel, San Francisco, Calif.

American Management Association. Production meeting. April 14–15, 1949, Hotel Statler, New York, N. Y.

American Society of Mechanical Engineers. 1949 Spring meeting. May 2–4, 1949; New London, Conn.

American Society for Metals. 6th Western Metal Congress and Exhibition. April 11–16, 1949, Shrine Auditorium, Los Angeles, Calif.

American Society for Testing Materials. 1949 Spring meeting. February 28–March 4, 1949, Edgewater Beach Hotel, Chicago, Ill.

American Society of Tool Engineers. 17th annual meeting. March 10–12, 1949, Hotel William Penn, Pittsburgh, Pa.

Chicago Production Show. Chicago Technical Societies Council. March 14–17, 1949, Hotel Stevens, Chicago, Ill.

Institute of Radio Engineers. 1949 annual convention. March 7–10, 1949, Hotel Commodore and Grand Central Palace, New York, N. Y.

Institute of Radio Engineers-Radio Manufacturers Association. Fourth annual Spring meeting. April 25–27, 1949, Benjamin Franklin Hotel, Philadelphia, Pa.

Instrument Society of America. Fourth annual Spring meeting. May 12–13, 1949, Royal York Hotel, Toronto, Ontario, Canada.

Midwest Power Conference. April 18–20, 1949, Sherman Hotel, Chicago, Ill.

National Association of Broadcasters. 27th annual convention. April 6–12, 1949, Hotel Stevens, Chicago, Ill.

National Association of Corrosion Engineers. Fifth annual conference and exhibition. April 11–14, 1949, Netherland-Plaza Hotel, Cincinnati, Ohio.

National District Heating Association. 40th annual meeting. May 24–27, 1949, The New Ocean House, Swampscott, Mass.

National Electrical Manufacturers Association. Winter convention. March 13–18, 1949, Edgewater Beach Hotel, Chicago, Ill.

National Electrical Wholesalers Association. May 2–6, 1949, Netherland Plaza Hotel, Cincinnati, Ohio.

National Fire Protection Association. May 16–19, 1949, Fairmont Hotel, San Francisco, Calif.

Third International Lighting Exposition and Conference. Week of March 28, 1949, Hotel Stevens, Chicago, Ill.

New Mining Magazine. *Mining Engineering*, a new magazine for mining engineers, will make its first appearance in January 1949, and will replace *Mining and Coal Technology* and *Mining and Metallurgy* magazines, the latter having been the official publication of the American Institute of Mining and Metallurgical Engineers for the past 29 years. To be distributed to AIME members and others in the mining field, each issue will contain operating articles and technical papers for the mining industry, plus news of the activities of AIME and its members.

Date Set for IRE 1949 Convention. The 1949 national convention of the Institute of Radio Engineers will be held from March 7 to 10, 1949, at the Hotel Commodore and Grand Central Palace in New York, N. Y. It will feature a technical program including 27 sessions on subjects embracing virtually the entire radio-electronic art, and six symposia, on nuclear science, network theory, electronic computors, radio aids to navigation, semiconductors, and marketing. Radio, in its most limited sense, will be covered, plus Loran, radar, and all other contributions with which radio engineers were affiliated in the last war will be discussed. Television also will be covered. Under the theme of "Spotlighting the New," nearly 200 exhibits of the latest developments and products of postwar research will be displayed. A center devoted entirely to nuclear instrumentation is being included. Four government organization and 186 business firms already have signed to provide displays and exhibits.

EJC Holds Milwaukee Meeting. The first Engineers' Joint Council meeting outside of the city of New York was held by the local sections of the Founder Societies at Milwaukee, Wis., on January 5, 1949. Featured speaker of the evening was Malcolm Pirnie, internationally known head of Malcolm Pirnie Engineers, consulting engineering firm, and recent recipient of the 1948 Hoover Medal of the four Founder Societies. The medal was conferred in New York on the opening day of the 96th annual meeting of the American Society of Civil Engineers, of which Pirnie is a past president. His talk at the Milwaukee meeting was on "Engineers Cannot Be Isolationists," a discussion of the obligations of the professional man to his country and his community. Pirnie has done much to fulfill his obligation as he has served as chairman of the National Engineers Council on the disarmament of Germany and Japan following World War II, and also as a consultant to the War Department. His service has extended to numerous other professional, public, and welfare groups.

NSPE Elects New Officers. The National Society of Professional Engineers, largest national organization of registered engineers, elected a new slate of officers for 1949 on January 1, 1949. The new president will be Alan G. Stanford, an electrical engineer and vice-president of Robert and Company, Inc., architects and engineers, Atlanta, Ga. Six prominent engineers from professional and educational ranks were elected to vice-presidencies to represent the society's six regional sections. Russell B. Allen, professor of civil engineering, University of Maryland, College Park, Md., retained the treasurership, and Paul H. Robbins continues as executive director.

HONORS • • • • • • •

McAuliffe Wins AIME Award. Eugene McAuliffe, retired chairman of the board, Union Pacific Coal Company, Omaha, Nebr., will be the first recipient of the Erskine Ramsay Award of the American Institute of Mining and Metallurgical Engineers. The award was established recently to recognize

distinguished achievement in the production, beneficiation, or utilization of bituminous or anthracite coal. The citation for the award, which will be conferred on McAuliffe at the annual banquet of the institute in San Francisco, Calif., on February 16, 1949, states that it is presented "for his leadership and initiative in the promotion and achievement of better safety, more efficiency, and improved working conditions in coal mining, which has led to a more healthy coal industry."

ASME Presents Awards to Noted Scientists

The American Society of Mechanical Engineers conferred its 1948 national awards to leading American men of science at the Honors Night dinner of its 69th annual meeting in New York, N. Y., December 1, 1948. The ASME Medal, highest honor of the society, went to Doctor F. G. Keyes, head of the department of chemistry, Massachusetts Institute of Technology, for his distinguished service to science and engineering.

E. S. Cole, codeveloper of the Pitometer log device to measure speed and distance aboard ships, and president of the Pitometer Log Corporation, was awarded the Worcester Reed Warner Medal for the development of his invention and for his work connected with it. The Holley Medal, for scientific and engineering achievement, went to E. H. Land, president of the Polaroid Corporation, for his work in polarized light and optics, and his research and developments of war weapons in World War II. Doctor T. von Karman received the John Fritz Medal in person, the award having been made in February 1948.

Von Karman Appointed Honorary Professor. Doctor Theodore von Karman, director of the Guggenheim Aeronautics Laboratory at the California Institute of Technology, has been appointed an honorary professor of mechanical engineering at Columbia University, New York, N. Y. The distinction, rarely conferred, is in recognition of his outstanding achievements in the field of aerodynamics. Doctor von Karman is best known for his theories of vortex motion and turbulence in fluids and for his work in supersonic aerodynamics. He is a consultant to the Northrop Aircraft Company, the General Electric Company, and the Aerojet Engineering Corporation.

LETTERS TO THE EDITOR

INSTITUTE members and subscribers are invited to contribute to these columns expressions of opinion dealing with published articles, technical papers, or other subjects of general professional interest. While endeavoring to publish as many letters as possible, Electrical Engineering reserves the right to publish them in whole or in part or to reject them entirely. Statements in letters are expressly understood to be made by the writers. Publication here in no wise constitutes endorsement or recognition by the AIEE. All letters submitted for publication should be typewritten, double-spaced, not carbon copies. Any illustrations should be submitted in duplicate, one copy an inked drawing without lettering, the other lettered. Captions should be supplied for all illustrations.

Use of Thevenin's Theorem

To the Editor:

Engineers should be grateful for I. Cogan's letter (*EE, Nov '48, p 1127*) which draws their attention once again to applications of Thevenin's theorem. Though this theorem is used by every student and engineer in simple series circuits (where the application is often unwitting), its generality and its application to the solution of network problems could have much wider appreciation.

Perhaps the theorem has not found favor because its use may require that type of thought which is needed to solve geometrical (or even cross-word) puzzles. Many engineers will prefer more routine methods of attack, such as the star-mesh transformation, to handle the solution of a network.

Mr. Cogan seems to have been unfortunate in his illustration; for all that he appears to have done is to have proved the star-mesh transformation for a particular 3-ray star. Thevenin's theorem would seem to fail to give a proof of the transformation for more than three rays, but Mr. Cogan's method applies to any 3-ray star. Thus, using the notation of his Figure 2, the current in line A must be given by electromotive force $E_{AB}+E_{BC}\cdot\frac{Z_3}{Z_3+Z_3}$ in series with impedance $Z_1+\frac{Z_2Z_3}{Z_2+Z_3}$ giving

$$I_A = E_{AB}\cdot\frac{Z_1+Z_3}{\Sigma Z_1Z_3}+E_{BC}\cdot\frac{Z_3}{\Sigma Z_1Z_3}$$

$$= E_{AB}\cdot\frac{Z_1}{\Sigma Z_1Z_3}+(E_{AB}+E_{BC})\frac{Z_3}{\Sigma Z_1Z_3}$$

$$= E_{AB}\cdot\frac{Z_3}{\Sigma Z_1Z_3}-E_{CA}\cdot\frac{Z_3}{\Sigma Z_1Z_3}=I_1-I_3$$

where I_1, I_3, I_A are the currents in the arms of the equivalent mesh, which has impedances of the well-known form:

$$\frac{\Sigma Z_1Z_3}{Z_2}=Z_1Z_3\cdot\Sigma\frac{1}{Z_1}\text{ between lines }A\text{ and }B,$$

$$\frac{\Sigma Z_1Z_3}{Z_1}=Z_2Z_3\cdot\Sigma\frac{1}{Z_1}\text{ between lines }B\text{ and }C,$$

$$\frac{\Sigma Z_1Z_3}{Z_3}=Z_1Z_2\cdot\Sigma\frac{1}{Z_1}\text{ between lines }C\text{ and }A.$$

R. H. ANGUS (A '31)
(University lecturer, Engineering Laboratory, Cambridge, England)

Dimensions of Resistivity

To the Editor:

I read with interest William E. Warden's question in the January issue (*p 92*) about the use of the dimensions ohms per circular mil-foot in expressing the resistivity of a material. The solution to his problem lies in the fact that ohms per circular mil-foot is not meant to be the dimensions of resistivity. The true dimensions are, as Mr. Warden indicated, ohm-circular mils per foot.

The numerical value of ohms per circular mil-foot for any given material is exactly what this dimensional expression indicates if interpreted literally: the number of ohms one measures in a sample of the material whose length is one foot and whose area is one circular mil. That this is numerically equal to the resistivity in ohm-circular mils per foot is evident upon consideration of the general formula for the resistance of a conductor: $R=\rho\frac{L}{A}$. When L equals one foot and A equals one circular mil, this reduces to $R=\rho$. The numerical values thus found may be used for the resistivity of the material.

J. W. Williamson's letter in the November issue (*p 1129*) dealt with this difficulty in relation to the expression ohms for a centimeter cube (more frequently written ohm-cm). The numerical value of ohm-cm is the resistance of a cube one centimeter on each side ($L=1$ centimeter and $A=1$ centimeter^2). That this value is equal in magnitude to the resistivity in ohm-cm is obvious.

These peculiarities are the results of the confusion in the use of dimensions for some electrical quantities which is only slowly being dispelled. The seriousness of such confusion may be seen from the puzzlement caused in this case by the use of faulty dimensions for so basic a quantity as resistivity.

JACK HILIBRAND
(Student, The City College of New York, N. Y.)

Nonuniform Coil Windings

To the Editor:

In the design of iron-cored coils, the usual assumption made is that every turn of wire through which the current flows contributes the same amount to the magnetic field in the core. This assumption holds very nearly as long as the magnetic path goes through materials of high permeability.

Thus a turn near the outside of the coil contributes no more nor less to the magnetic field than one near the inside—yet its electrical resistance is often several times as great as that of a turn near the inside. If the designer is interested in keeping the copper losses small, he should attempt to have all the turns near the inside; that is, make the coil very thin. A possible way for decreasing the copper loss in a thick coil is to use different wire sizes: that is, wind a few layers with thin wire on the core, then build up the outer layers with thicker wire.

From the theoretical point of view, the best results that can be obtained in this manner are shown in Figure 1, where n represents the number of wire sizes used in winding the coil, r is the ratio of outside to inside diameter of the coil, and E is the resistance the coil would have if the same size coil wound with uniform wire had a resistance of 100 ohms.

It is readily apparent that if the designer is interested in squeezing the last few per cent

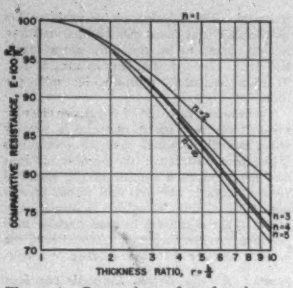


Figure 1. Comparison of total resistance of different windings

of efficiency out of his coil, it can be done by using several wire sizes in the winding; however, for most applications, the uniform winding seems to be good enough.

The computations necessary to arrive at a winding schedule using standard wire sizes are rather lengthy, and only the final results will be given here:

$$N_1 = L\left(p^2B - \frac{a}{y_1^2}\right)$$

$$N_k = LB(p^2-1);\quad k=2,\ 3,\ \ldots\ n-1.$$

$$N_n = l\left(\frac{b}{y_n^2} - B\right)$$

w ere

a = inside radius of winding

b = outside radius of winding

n = number of different wire sizes used

p = ratio between successive wire diameters = y_k/y_{k-1}

y_k = wire diameter in the kth set of layers

$$B = \frac{1}{(n-1)(p^2-1)}\left(\frac{N}{L} + \frac{a}{y_1^2} - \frac{b}{y_n^2}\right)$$

L = length of coil

N = total number of turns

N_k = number of turns in the kth set of layers.

CLAUDE L. EMMERICH

(Research Fellow, Graduate department of applied science, University of Cincinnati, Cincinnati, Ohio)

Electrical Essay

To the Editor:

Doctor Slepian is conducting a very interesting series of electrical essays which contributes very much to the reading of

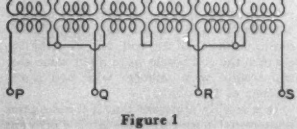


Figure 1

ELECTRICAL ENGINEERING and stimulates thinking in terms of fundamentals. This is to contest the answer to the November essay (*EE, Nov '48, p 1073*) which is published on page 1141 of the December 1948 issue and especially the sentence: "The remaining two transformers may be left unexcited, or connected in any way which will leave the foregoing arrangement essentially unaltered."

The problem specifies six transformers to be connected and to be energized in any desired manner to obtain the desired voltage readings. The connections shown in Figure 1 of this letter are suggested and four voltages of two frequencies, the pairs of the same frequency being in quadrature with respect to each other are required. For example, assume voltages to be: $V_1 = 70.7 \sin \omega t$; $V_2 = 70.7 \cos \omega t$; $V_3 = 70.7 \cos 3\omega t$; $V_4 = 70.7 \sin 3\omega t$. Then an rms voltmeter will read 100 volts across any pair of the terminals P, Q, R, and S.

This solution requires the use of all six transformers and leaves no "loose ends" to be disposed of in some undeterminate manner.

A. A. KRONEBERG (F '48)

(Southern California Edison Company, Los Angeles, Calif.)

PAMPHLETS • • • • •

The following recently issued pamphlets may be of interest to readers of "Electrical Engineering." All inquiries should be addressed to the issuers.

NEMA Standards Booklets and Reports. Publication 48-134, "NEMA Definitions for Marine-Propulsion Gas Turbines," covering terms used in marine-propulsion gas turbines, gas turbine power plants and components, and power plant performance. 12 pages, $1.25 per copy; "EEI-NEMA Report on Single-Phase Motor Starting Current Rules," publication 116, containing starting problems and outlining typical applications of rules. 8 pages, 25 cents a copy; "NEMA Standards for Shaft Couplings." 12 pages, 45 cents a copy; "Index to NEMA Standards Publications," available upon request. National Electrical Manufacturers Association, 155 East 44th Street, New York 17, N. Y.

Publications on Corrosion. "Bibliographic Survey of Corrosion, 1945." Contains about 1,100 references to published articles and 170 references to patents concerned with corrosion. 129 pages, cloth-bound, $5 per copy; "Directory of the American Coordinating Committee on Corrosion," listing the names, addresses, and specialty of principal corrosion workers in the United States and Canada. 62 pages, $2 a copy. Both for sale by the National Institute of Corrosion Engineers, 905 Southern Standard Building, Houston 2, Tex.

Some Studies of Ohio Coals, Shales, and Oils. Ohio State University Engineering Experiment Station Bulletin 133. Includes sampling and testing procedure and grades and standards. Price $1 from the Engineering Experiment Station, Ohio State University, Columbus 10, Ohio.

NEW BOOKS • • • • •

The following new books are among those recently received at the Engineering Societies Library. Unless otherwise specified, books listed have been presented by the publishers. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books in question.

DIRECT-CURRENT MACHINERY. By R. G. Kloeffler, R. M. Kerchner, J. L. Brenneman. Revised edition. Macmillan Company, New York, N. Y., 1948. 395 pages, illustrations, diagrams, charts, tables, 9½ by 6 inches, cloth, $5.75. This book is intended for junior students in electrical engineering. In revising the text, the latest information on new theories, developments and applications were included. To the machines previously considered have been added the amplidyne, multifield exciters, the welding generator, and airplane generators. The newer theories of commutation and current methods of automatic starting and control are treated in some detail. The problems have been increased in number and scope.

ELASTICITY AND ANELASTICITY OF METALS. By C. Zener. University of Chicago Press, Chicago, Ill., 1948. 170 pages, illustrations diagrams, charts, tables, 9¼ by 6 inches, cloth, $4. Of interest to physicists, metallurgists, and engineers, this book presents the science of the nonelastic behavior of metals at low stress levels. It considers the various types of an elasticity and develops their interrelations. A review is given of the various types of relaxations which have been found to give rise to an elasticity, and also of the dependence of the elastic properties of a metal upon its microstructure. Over 200 references are cited. The author points out the role which studies of this behavior will play in the future development of metallurgical science.

ELECTRICITY SUPPLY METERS. By A. E. B Perrigo. Chapman and Hall, Ltd., London, England, 1947. 356 pages, illustrations, diagrams, tables, 9¼ by 5½ inches, cloth, 32s. This book is planned to aid the meter engineer who wishes to become familiar with the fundamentals of electricity meters and all instruments employed in their calibration. A sound fundamental knowledge of electrical phenomena, trigonometry, elementary calculus, and vector summation is assumed. A wide variety of instruments is considered, including the proper apparatus and layout for a test room.

ELEMENTS OF PHYSICS. By A. W. Smith. Fifth edition. McGraw-Hill Book Company, New York, N. Y., Toronto, Ontario, Canada, London, England, 1948. 745 pages, illustrations, diagrams, charts, tables, 9¼ by 6 inches, cloth, $5. The fifth edition of this standard text continues to introduce students to physics as a way of thinking. Illustrations and applications have been selected from a wide range of experiences in order to enable the student to see the relation between physical principles and the activities of life. New material added includes a chapter on meteorology, and discussions of aerodynamics, the flow of fluids, the electron microscope, cyclotron, betatron, and electrostatic generator.

ENGINEERING CONTRACTS AND SPECIFICATIONS. By R. W. Abbett. Second edition. John Wiley and Sons, Inc., New York N. Y., Chapman and Hall, Ltd., London, England, 1948. 327 pages, charts, 8½ by 5½ inches, cloth, $3.75. The purpose of this book is to present some of the legal and business aspects of the engineering profession. In contrast to the first edition, increased emphasis is placed upon contract procedure for private work, although the original material on government methods has been retained and brought up to date. An entirely new chapter on construction insurance has been added, and the sections on prequalification and arbitration have been rewritten and expanded. Much new material on specification writing has been added.

MECHANICS. By J. P. Den Hartog. McGraw-Hill Book Company, New York, N. Y., Toronto, Ontario, Canada, London, England, 1948. 462 pages, illustration, diagrams, 9¼ by 6 inches, cloth, $4.50. Covering the usual sophomore course in engineering mechanics, this text presents the subject in a clear and simple manner, with emphasis on the fundamentals of statics, kinematics, and dynamics. One of the outstanding features is the collection of 334 problems provided at the end of the book.

Powerful argument for men who buy cable...

KERITE lasts a long, long time . . . stands up well under most any conditions of temperature, weather, moisture, etc. . . . is good security against service outages . . . saves you money.

In short, Kerite makes your cable dollars go farther. *That*, we think, is a powerful argument for anyone who buys cable.

We can back it up with other powerful arguments, too. For instance—we can show you samples of Kerite cable more than 60 years old that are still mechanically and electrically in first-class condition. And we can point out that the same wonderful ingredient—Kerite—is used in the cable we make today as was used in that cable which has stood up so well.

And we might mention that no matter how old a company may be, it has to stay young to merit the continued business of astute buyers.

These powerful arguments—we think—will demonstrate why Kerite cable assures you of low cost per year. When you buy Kerite, the facts will back up your judgment—and the performance will bear it out. The Kerite Company, 30 Church Street, New York 7, N. Y.

Kerite Insulation—Your Cable's Best Life Insurance

KERITE CABLE

THE NEW MOLONEY

The new Moloney HiperCore Distribution Transformers incorporate advanced engineering practices and simplicity of construction, plus the usual Moloney high factor of safety in design. Cores are wound of high permeability, oriented, silicon steel having 30% to 35% greater flux carrying capacity than hot rolled steel. This makes it possible to decrease the amount of steel, copper and other materials, and at the same time improve the operating characteristics.

HiperCore Transformers with wound cores, are lighter in weight and smaller in size than transformers having cores of non-oriented steel. They have greater short-time overload capacity and provide better voltage regulation. Simple construction, together with low winding temperature gradient, results in trouble-free operation and longer life under all loading conditions. HiperCore Transformers are made in sizes 50 Kva and smaller, in voltage classes 15 Kv and below. Available in both Conventional and CSP Type of single-phase transformer.

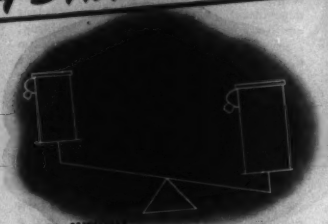
HiperCore*

...ICON STEEL

DISTRIBUTION TRANSFORMERS

4 STAR FEATURES

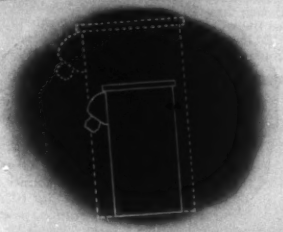
1



LIGHTER WEIGHT

The 30% to 35% higher flux carrying capacity of the oriented core steel used in HiperCore Transformers makes possible the use of smaller cores and windings, with consequent reductions in the weights of steel, copper, oil, and other materials. HiperCore Transformers weigh 15% to 30% less than transformers having cores made of hot rolled steel, making them easier to handle and install.

2



SMALLER SIZE

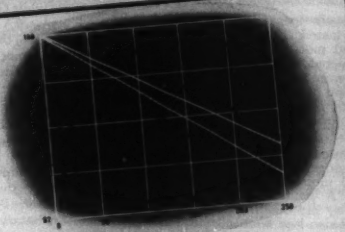
Since the higher flux carrying capacity of oriented steel permits the use of smaller cores and windings, smaller tanks can be used. Reductions in size range up to 30%. HiperCore Transformers take up less space on the pole, in the storeroom, and on the line truck.

3

GREATER SHORT-TIME OVERLOAD CAPACITY

Moloney HiperCore Transformers have improved short-time overload characteristics which provide better peak load performance and longer life. Reduced coil mass, achieved through use of oriented steel cores, together with the extensive use of cooling ducts, results in more rapid cooling of the windings and in a lower hottest-spot temperature gradient.

4



BETTER VOLTAGE REGULATION

The smaller cores of HiperCore Transformers make possible windings having lower impedance. Lower impedance provides lower internal voltage drop at all loads. This is especially important during peak load periods, since HiperCore Transformers can carry higher overloads than older types, at the same permissible regulation.

MOLONEY ELECTRIC CO.

Power and Distribution Transformers Exclusively Since 1896

FACTORIES AT ST. LOUIS 20, MISSOURI AND TORONTO, ONTARIO, CANADA

Silicone News
DC
CORNING

Silicone Insulation Gives Rapidly Reversing Motor 10 Times Normal Life

That's significant news to designers of machine tools. Even more significant perhaps to electrical engineers is the further confirmation of our laboratory and motor test results. These tests indicated that Silicone Insulation has 10 times the life and 10 times the wet insulation resistance of Class 'B' insulation under comparable conditions.

PHOTO COURTESY COGSDILL TWIST DRILL COMPANY

Improved drill grinder depends upon DC Silicone Insulation for long trouble-free operation.

Engineers at Cogsdill Twist Drill Company of Detroit developed a unique machine for grinding drills. Instead of reversing the carriage by a conventional cam or crank, they use a 1 h.p., 1200 r.p.m. motor to reverse the carriage drive 50-60 times per minute.

In this service, Class 'A' insulated motors lasted 3 to 4 days; Class 'B' insulated motors lasted 3 to 5 weeks. After repeated failures, the reversing motors were rewound with DC Silicone Insulation by the A. H. Nimmo Electric Company of Detroit.

The motor bearings were packed with DC 44 Silicone Grease and the frame was painted with DC Silicone enamel. The motors have now been in service over 10 months and show no sign of failure. A hazardous smoke problem caused by the burning of conventional finishes also has been eliminated.

This is a typical example of how Dow Corning Silicone Insulation increases the life and reliability of hard working motors. Specifications for rewinding ac motors are given in data sheet G6A.

DOW CORNING CORPORATION
MIDLAND, MICHIGAN
Atlanta • Chicago • Cleveland • Dallas
Los Angeles • New York
In Canada: Fiberglas Canada, Ltd., Toronto
In England: Albright and Wilson, Ltd., London

Dow Corning
FIRST IN SILICONES

INDUSTRIAL NOTES ....

A. H. Smith Elected Vice-President of Kerite. At a December 1948 meeting of the board of directors of the Kerite Company, Arthur H. Smith was elected a vice-president. He has held the position of railroad sales manager for the company since 1945.

Westinghouse Appointments. Roscoe Seybold, vice president of the Westinghouse Electric Corporation, has been appointed assistant to the president, with special responsibility for organizational planning and budget and operating expense control. C. E. Headlee has been elected controller, a position held by Mr. Seybold since 1931. Also recently appointed are William A. Beatty, who now is manager of the feeder division; and Leonard H. Loufek as industrial manager of the company's central district. He succeeds C. H. Weaver, who has been named manager of the newly-formed atomic power division of Westinghouse.

GE Notes. General Electric company has leased the former Remington Rand Plant in Johnson City, N. Y., from the War Assets Administration, to manufacture special equipment for the Air Force which will furnish production facilities in the plant. Walter B. Booth, formerly division superintendent of the carbon products division of the Schenectady plant, has been appointed plant manager of the new Johnson City factory. New appointments include those of Wilmer P. Hauck, to the position of manager of manufacturing of General Electric Company's heat device factories at Bridgeport. At Schenectady, Arthur H. Hemker has been appointed manager of the farm industry division, while George A. Rietz, former manager, replaces A. C. Stevens, recently retired, as manager of the educational service section in the customer relations division of the General Electric executive department.

Moloney Electric Gets Hungry Horse Contract. The Moloney Electric Company of St. Louis, Mo., has recently been awarded a contract for supplying the main power transformers for the Bureau of Reclamation's Hungry Horse Project, located on a Columbia River tributary, near Kalispell, Montana. The contract covers six 60,000 Kva, single-phase transformers, which will be used to step up the generator bus voltage of 13,800 volts to 230,000 volts for transmission. The company also announces the appointment of Edwin C. Mulcahy as vice president in charge of sales.

New President for RCA. Frank M. Folsom, formerly executive vice president in charge of RCA Victor division, took office as president of Radio Corporation of America in January. Mr. Folsom's former position will be filled by John G. Wilson.

Cornell-Dubilier Purchases RCA Capacitor Plant. All equipment, designs, processes, and patent licenses of the Faradon Capacitor Division of the Radio Corporation of America has been purchased outright by the Cornell-Dubilier Electric Corporation of South Plainfield, N. J. Production of Faradon capacitors is now being continued under the new owner.

Porcelain Insulator Corporation Completes Plant Addition. The first half of a six-year expansion program of the Porcelain Insulator Corporation of Lima, N. Y., has been realized with the completion of a new addition located at the south end of the plant. The addition, 209 feet long, houses a modern machine shop and tool crib, mold manufacturing department, and a plant maintenance department. Other new buildings and plant additions include a mold storage building; a storage building for PINCO transmission line hardware; an oil storage building and a new transformer bushing and switch insulator assembly department, an enlargment of the engineering department, and new, completely equipped, lecture quarters.

New Test Instrument Company. James W. Dice, formerly with Westinghouse Electric Corporation, and recently assistant sales manager of Sperry Products, has formed a new sales and development organization to be known as J. W. Dice and Company. The new company is located at Grand View-on Hudson, N. Y., and specializes in the marketing of industrial and laboratory nondestructive test instruments employing magnetic, electronic, ultrasonic, and radiation principles.

D. J. Burns Resigns as President of Ward Leonard Electric. Dawson J. Burns, at a recent meeting of the board of directors of the Ward Leonard Electric Company, resigned as president. He then was elected to the office of chairman of the executive committee. Mr. Burns had been a member of the board of directors since 1903, serving the company as vice-president from 1908 to 1944 at which time he was elected president. Arthur A. Berard, executive vice-president and general manager of the company since 1944, was elected president and general manager. Mr. Berard, who joined the company in 1920, has been a member of the board of directors since 1927 and has served as factory manager and general sales manager.

Fairchild Recording Equipment Corporation Formed. To combine the manufacture and sale of a new professional studio quality magnetic-tape recorder with the line of professional disk-recording and sound equipment of Fairchild Camera and Instrument Company, a new company has been formed with offices at 30 Rockefeller Plaza, New York, N. Y. It will serve the specialized requirements of the radio-broadcast industry, as well as the strict requirements demanded by the art of record and transcription manufacture, and also

(Continued on page 26A)

YOU GET QUALITY PLUS ENGINEERING SERVICE WITH G-E PERMANENT MAGNETS

The magnet shown is 10 times actual scale and is the heart of the Magnetic Relay manufactured by Thomas A. Edison, Incorporated, West Orange, New Jersey.

The Magnet that Sounds the Alarm

Here's a unique application for G-E permanent magnets. As the moving element in the Edison Sensitive Relay, a tiny G-E Sintered Alnico 5 permanent magnet completes an electrical circuit . . . instantly sounding the alarm for fire.

Design specifications for this magnet application were severe. Extremely high pole tip density was required. Yet mass had to be low. Cost conscious G-E engineers worked closely with Thomas A. Edison, Incorporated. Costs were cut by redesign and by the use of Sintered Alnico 5 . . . a new magnetic alloy recently developed by General Electric.

Perhaps your permanent magnet costs can be reduced. Our design engineers will be glad to work with you to improve your product. Remember, too, that General Electric produces all grades of CAST and SINTERED ALNICO as well as special magnetic alloys for your product.

Edison Aircraft Fire Detection System—Fast, Safe, Dependable

Here's how the Sensitive Magnetic Relay fits into the Edison Fire Alarm system. An Edison thermocouple detector mounted in the area to be protected generates its own emf when a dangerously rapid rise in temperature occurs. This emf (measured in *millivolts*) actuates the Sensitive Magnetic Relay and sets off a fire alarm. When the fire is out and conditions return to normal, the detectors signal "Fire Out" and are again ready to signal "Fire" rapidly and truthfully.

CHEMICAL DEPARTMENT, SECTION 12-2
GENERAL ELECTRIC COMPANY
PITTSFIELD, MASS.

Please send me:
( ) Bulletin, CDM-16, "G-E Permanent Magnet Subassemblies"
( ) Bulletin CDM-2A, "G-E Permanent Magnet Catalog"

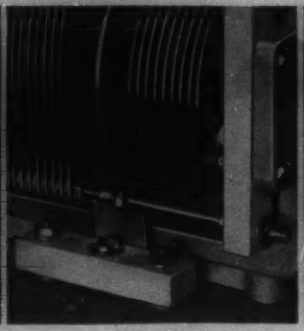
Name ..... Title .....
Company .....
Products Mfrd .....
Address .....
City ..... State .....

PERMANENT MAGNETS

GENERAL ELECTRIC

CDeb-A1

This 50-to-1 worm drive, equipped with a 3½ inch dial, is used for the fine setting adjustment. Backlash is kept very low by spring pressure on the worm shaft. Eccentricity from set screws and misfit is eliminated by cutting the worm and its shaft from an integral steel shafting.



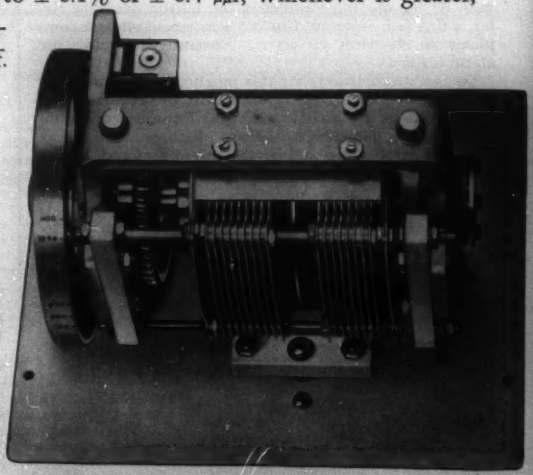
Two small, waxed steatite bars insulate the stator plates. A Figure of Merit (Dissipation Factor x Capacitance) of 0.04 μμf is secured (0.003 μμf with quartz insulators). Connection to the rotor is through spring-tempered silver alloy brushes bearing on a silver-overlay brass disc.

The worm shaft is held to a tolerance of 0.0004 inch; radial eccentricity of the worm gear is less than 0.002 inch. The main rotor shaft is held to a tolerance of 0.0005 inch and its bearing surfaces to 0.0002 inch. Ball bearings are used on worm and main rotor shafts.

The STANDARD of Variable Capacitance

Recently the accuracy of the well-known G-R Type 722 Precision Condensers has been increased, making these standards of variable capacitance of even greater use in the laboratory and as the variable element in many instruments such as oscillators and frequency meters.

Typical of the three different models of this condenser is the Type 722-N, with extra low metallic resistance and inductance. This condenser (illustrated) is direct reading to ± 1 μμf. When the corrections (charted on the front panel) are applied to the direct-reading settings the accuracy is increased to ± 0.1% or ± 0.4 μμf, whichever is greater, and the corresponding accuracy for capacitance differences is ± 0.1% or ± 0.5 μμf.



SPECIFICATIONS

- **CAPACITANCE RANGE:** 100 to 1100 μμf, direct reading
- **STANDARD CALIBRATION:** Direct reading in μμf at 1 kc to ± 1 μμf. Mounted correction chart gives corrections to 0.1 μμf at multiples of 100 μμf.
- **WORM CORRECTION:** For very precise measurements a worm correction calibration can be supplied. When these are applied capacitance can be determined within ± 0.1 μμf or ± 0.1%, whichever is greater, and capacitance differences to ± 0.2 μμf or ± 0.1%
- **METALLIC RESISTANCE:** Series resistance about 0.008 ohm at 1 Mc
- **SERIES INDUCTANCE:** Approximately 0.024 μh
- **TEMPERATURE COEFFICIENT:** Approximately 0.002% per deg. C.

- **TYPE 722-N PRECISION CONDENSER** **$160**
  Worm Correction Calibration **50**
  Quartz Insulation **85**

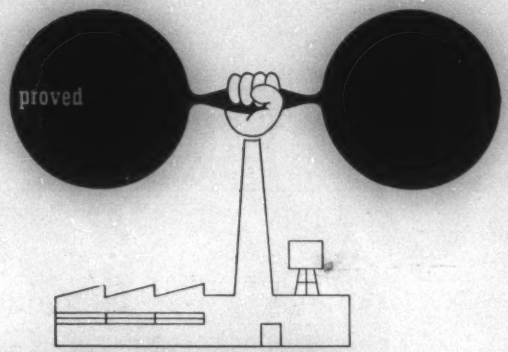
GENERAL RADIO COMPANY Cambridge 39, Massachusetts
90 West St., New York 6 920 S. Michigan Ave., Chicago 5 1000 N. Seward St., Los Angeles 38

improve

power loadability in

your plant

with field-tried capacitors of proved dependability



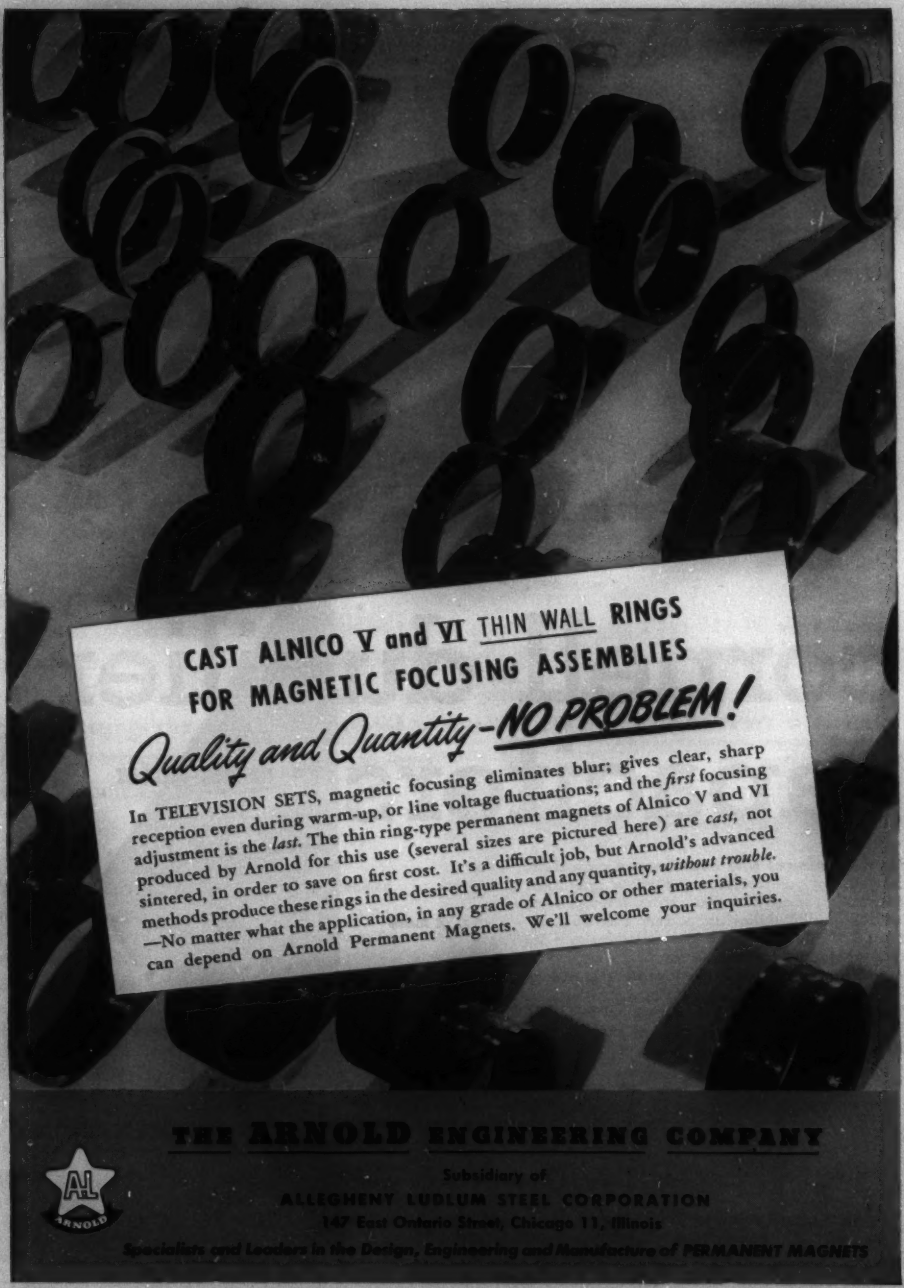
proved in the field – not for 1 year, but for over 10 years!

cornell-dubilier capacitors

Why experiment with experimental capacitors? Over 10 years of continuous, trouble-free operation give you convincing proof that you get more for your money with Cornell-Dubilier capacitors. 800,000 kva. — a total of more than 3,500 field installations — demonstrate the overwhelming preference for C-D's by leading power engineers. Write today for literature or call your C-D field man for analysis of your specific power-factor problem. Cornell-Dubilier Electric Corporation, Dept. B-29 South Plainfield, New Jersey. Other plants in New Bedford, Worcester, Brookline, Massachusetts; and Providence, Rhode Island.

CORNELL-DUBILIER • WORLD'S [illegible] MANUFACTURER OF CAPACITORS

Follow the leaders.
Demand dependable C-D Capacitors for your plant.


CAST ALNICO V and VI THIN WALL RINGS
FOR MAGNETIC FOCUSING ASSEMBLIES
Quality and Quantity—NO PROBLEM!
In TELEVISION SETS, magnetic focusing eliminates blur; gives clear, sharp reception even during warm-up, or line voltage fluctuations; and the first focusing adjustment is the last. The thin ring-type permanent magnets of Alnico V and VI produced by Arnold for this use (several sizes are pictured here) are cast, not sintered, in order to save on first cost. It's a difficult job, but Arnold's advanced methods produce these rings in the desired quality and any quantity, without trouble. —No matter what the application, in any grade of Alnico or other materials, you can depend on Arnold Permanent Magnets. We'll welcome your inquiries.
THE ARNOLD ENGINEERING COMPANY
Subsidiary of
ALLEGHENY LUDLUM STEEL CORPORATION
147 East Ontario Street, Chicago 11, Illinois
Specialists and Leaders in the Design, Engineering and Manufacture of PERMANENT MAGNETS

TO ELIMINATE
CONTROL CIRCUIT FAILURE...

Specify

Rome Control Cables

RUBBER
NEOPRENE
THERMOPLASTIC

7 Conductor Control Cable, 19/25 AWG—RoMarine insulation with individual conductor sheath of Neoprene—RoPrene (Neoprene) sheath over all—600 Volts.

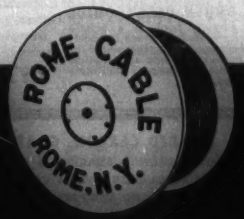
Protect those vital control circuits . . . the "nerve system" of your whole distribution network . . . with the dependability of Rome Control Cables. You can ill afford the loss of revenue and customer good will when outages occur from control circuit failure. As a matter of fact there is no need to run that risk. Rome Control Cables are manufactured to one standard of quality . . . the highest . . . and carry with them a sense of responsibility for dependable and unfailing service.

*TRADEMARK REGISTERED

In Rome Control Cables, too, you will find variety of construction to meet your particular requirements. In the design of individual conductor insulation, as well as outer protective sheath, Rome Synthinol* thermoplastic, rubber, and Neoprene compounds can be combined, or used separately, to provide the ultimate in service performance. Typical Control Cable constructions are described in Specifications **CT-1, CRM-1** and **CRO-1.** Write for your copies today.

FROM BAR TO FINISHED WIRE

ROME CABLE
CORPORATION
ROME · NEW YORK



Money and Commutator Saving Brushes for AC-DC Motors

Write for fractional
H. P. BRUSH USER'S GUIDE
This 44-page book is a helpful guide for evaluating brush materials and choosing the one best suited for your particular motor and application. Write on company stationery for a copy.

Without exception, leading makers of small AC-DC motors who have used Stackpole grades of brushes *have reported materially longer brush life and less commutator wear!*

Although some new Stackpole brush grades have high specific resistance, their contact drop is such that both motor speed and torque are essentially the same as when conventional electrographitic brush grades are used. Mechanical strength is exceptionally high—a particularly desirable characteristic in small universal motor brushes. Also, various Stackpole brush grades have shown excellent results on AC-DC motors having undercut mica as well as those with the flush mica commutator bar type of insulation.

TEST SAMPLES TO QUANTITY USERS . . .

The one way to tell about motor brushes is to try them on your own equipment, under actual operating conditions. We're so confident that Stackpole Brushes will show you a real saving that, providing you are a quantity user of small universal motor brushes, we'll gladly send samples for test. Give full details of your motor rating, application, and brush data.

STACKPOLE CARBON COMPANY • ST. MARYS, PA.

"EVERYTHING IN CARBON BUT DIAMONDS"

MOLDED CARBON, GRAPHITE AND POWDERED METAL SPECIALTIES . . . *Write for details on any type*
BATTERY CARBONS • BEARINGS • BRAZING FURNACE BOATS • BRUSHES • CARBON, GRAPHITE AND METAL CONTACTS • CARBON VOLTAGE REGULATOR DISCS • CHEMICAL CARBONS • CLUTCH RINGS • DASH POT PLUNGERS • POWER TUBE ANODES • RESISTANCE WELDING AND BRAZING TIPS • SEAL RINGS • SPECIAL MOLDS AND DIES • TROLLEY AND PANTOGRAPH SHOES • WATER HEATER & PASTEURIZATION ELECTRODES • WELDING CARBONS, ETC.

HERE COMES THE

Trumbull Train

OF ELECTRICAL PROGRESS

A whole parade of new Trumbull products is headed your way! A new advancement in the entire line of Trumbull products — Flex-A-Power systems, Panel Boards, Control Centers, Switches and Motor Starters — all radically different. So watch for Trumbull's new product announcements during 1949. Here's the first —

A NEW

Magnetic Motor Starter and Magnetic Contactor

New, from top to bottom, Trumbull Starters and Contactors in sizes 0, 1, 2, 3 give maximum protection to motors up to 50 hp, 440 v. Look at all their important new advantages:

LONGER CONTACT LIFE —
Actual factory tests show the silver contacts on the Trumbull starter "make and break" for millions of operations — many times more than any starter on the market.

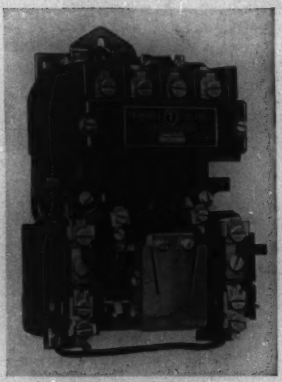
EASY TO MAINTAIN —
Silver contacts have permanently attached springs that are easy to remove. Terminals are located on the front and are easy to wire — a screw driver is all you need to disassemble starter — can be accomplished in less than a minute.

EASY TO INSTALL AND SERVICE —
Note convenient knockouts, large terminals, front connections, and ample wiring space.

GREATER PROTECTION —
Bi-metallic relay heaters follow motor's heating curve. Easily adjusted for automatic or manual reset.

BUILT TO LAST —
All parts resist corrosion and moisture. Examine plastic coil enclosure to see how the tough varnish impregnation protects windings. Contact points and cold-molded asbestos arc hood eliminate arcing . . . give clean "make and break" contact.

QUIET OPERATION —
Permanent lubricant impregnated in the plastic coil enclosure keeps magnet guides sliding smoothly . . . eliminates low voltage "chatter."



FOR MORE INFORMATION about this latest Trumbull development, write for Circular TEC 11. THE TRUMBULL ELECTRIC MANUFACTURING CO., Plainville, Conn. Other factories and offices throughout the United States. Foreign representation.

Men Who Observe the Best Electrical Practice Make It a Practice to Use

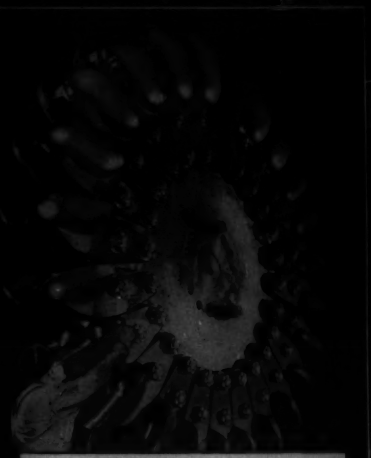
TRUMBULL (T) ELECTRIC

TRUMBULL'S TRAINLOAD OF NEW PRODUCTS

Allis-Chalmers Builds for Electric Utility Progress

NEW LIFE FOR

Runners of New Design, having die-formed vanes and other improvements, have replaced worn, inefficient runners for a Wisconsin hydro-electric station. New shafts were also furnished on these units.



New Buckets of improved design were used in the conversion of this bucket wheel from 50 to 60 cycle operation. It is one of the largest ever built.

Output Increased by approximately 15% when this replacement runner was installed at a large hydro plant on the Ohio River. It is specially designed to maintain capacity when operating under reduced head conditions.

1865—More than eighty years ago Allis-Chalmers built its first water-wheel . . . then in 1888, constructed a record-breaking screw pump which was forerunner of modern propeller-type turbine.

TODAY—Allis-Chalmers builds turbines, generators and distribution equipment for hydro projects the world over, with installations at such famous sites as Hoover, Shasta and Niagara.

ALLIS-

Pioneers in Power and

HYDRO POWER

Restoring or *Bettering* Original Performance of Turbines Is Job of Leading Hydro Power Builder

ALLIS-CHALMERS has recently modernized and rebuilt many existing hydraulic turbines . . . increasing their capacities, efficiencies, and span of service. Shown at left are typical examples of how hydro power stations benefit from A-C facilities for restoring turbines to new or better-than-new performance.

Installed horsepower of Allis-Chalmers turbines totals more than 10 million HP in all principal types—impulse, Francis and propeller. In addition to turbines and auxiliaries, Allis-Chalmers builds generators, power transformers and switchgear for the hydro power industry. It is the *only* company with centralized facilities for coordinating hydraulic and electrical experience.

These are some of the reasons why hydraulic power projects throughout the world look with confidence to Allis-Chalmers—one of the great names in hydro-electric power.

ALLIS-CHALMERS, 931A SO. 70 ST.
MILWAUKEE, WIS.

A 2575

Model runner tests authorized by owner of 30 year old power plant resulted in purchase of large new-design Francis runners (left) for improved performance.

Automatic cabinet-type governors like these have recently replaced less sensitive, manually operated equipment at power companies in Pennsylvania and in North Carolina.

ALLIS-CHALMERS A-C MILWAUKEE

CHALMERS

Electrical Equipment from Generation through Utilization

Welwyn Electrical Laboratories of Blyth, England, take pleasure in announcing the availability in the American Market of

1% HIGH STABILITY Carbon Resistors

proven over a decade in radar, communication and nucleonic apparatus. These cracked carbon resistors are available from 100 ohms to 50 megohms, with negligible voltage coefficient and temperature coefficient so low that all factors will not exceed the 1% tolerance—an accuracy they will hold for their life. *Individually noise tested before shipment*, they approach wirewound units in performance, and the minimum circuit noise determined by Johnson Formula.

Other Welwyn Resistor Products: Wirewound Resistors—in Vitreous Enamel and Cement Coatings—sized for 3 to 300 watts and capable of full dissipation.

Trimmer capacitors—air spaced with high ratio of maximum to minimum capacity—500 working volts—RMS.

Write for Descriptive Literature.

WELWYN ELECTRONIC COMPONENTS, INC.

234 East 46th Street New York 17, N. Y.

MUrray Hill 2-2535

DO *YOU* KNOW THE DIFFERENCE BETWEEN "ELECTRIC" & "ELECTRICAL"?

Electric means containing, producing, arising from, actuated by, or carrying electricity, or designed to carry electricity and capable of so doing.

Electrical means related to or associated with electricity but not having its properties or characteristics.

Definitions of some 4000 electrical terms—an invaluable aid to engineers, editors, scientists, technicians, and teachers—are published in the——

American and Canadian Standard—

DEFINITIONS OF ELECTRICAL TERMS

Price : $1.00

($1.25 outside postal USA)

Published by

American Institute of Electrical Engineers

33 West Thirty-Ninth St., New York 18

(*Continued from page 16A*)

will apply magnetic tape recording to industrial, motion picture, and aviation uses. Officers of the group are Sherman M. Fairchild, president; Wentworth Fling, operating vice-president; Hay H. Quinn, director of sales and advertising; C. V. Kettering, head of a sales division specializing in educational and industrial applications; Theodore Lindenberg, head of the instrument laboratory; and Gordon Mercer in charge of the electronic laboratory. John B. Wolf becomes secretary-treasurer. Doctor D. C. Hare has been retained by the new corporation as technical consultant and advisor.

Joint Electron Tube Engineering Council Appointments. Doctor A. K. Wright, chief radio engineer of the Tungsol Lamp Works, Inc., has been appointed member of the Joint Electron Tube Engineering Council. Doctor Wright has been active in the council's standardization program since its inception and was a former chairman of the receiving tube committee. Other appointments include Frank Langstroth of the Lansdale Tube Company, chairman of the receiving tube committee, and A. K. Wing, Jr., of Federal Telecommunication Laboratories, Inc., chairman of the high vacuum tube power committee.

Radio Manufacturers Failed Last Year. Twenty-nine radio and component manufacturers failed financially during the last fiscal year 1947–48 with liabilities totaling $123,912,000, the RMA Credit Committee reported during the 24th annual convention of the Radio Manufacturers Association at the Stevens Hotel, Chicago, Ill. The 29 manufacturers were classified as follows: radio receiver, 10; communications equipment, 5; test equipment, 3; television receivers, 2; recorders, 2; radio parts, 2; phonographs, 2; sound equipment, 1; motors, 1; projection, 1.

TRADE LITERATURE

Pressure and Vacuum Gauges; pH and Conductivity Control. The Brown Instrument Company has issued two new catalogs, the first, catalog number 15-12, features pH and conductivity control and their application to different industrial processes, as well as a discussion of the fundamentals involved. Catalog number 7000 offers a full description of pressure and vacuum gauges (indicating, recording, and controlling). Request copies from the Brown Instrument Company, Wayne and Roberts Avenues, Philadelphia 44, Pa.

Advance Relay Catalog. An illustrated catalog containing the entire line of advance relays, complete with descriptive detail. Write to Advance Electric and Relay Company, 1260 West 2nd Street, Los Angeles 26, Calif.

How Power at Load Centers Pays Off. This 16-page bulletin, recently issued by

(*Continued on page 30A*)

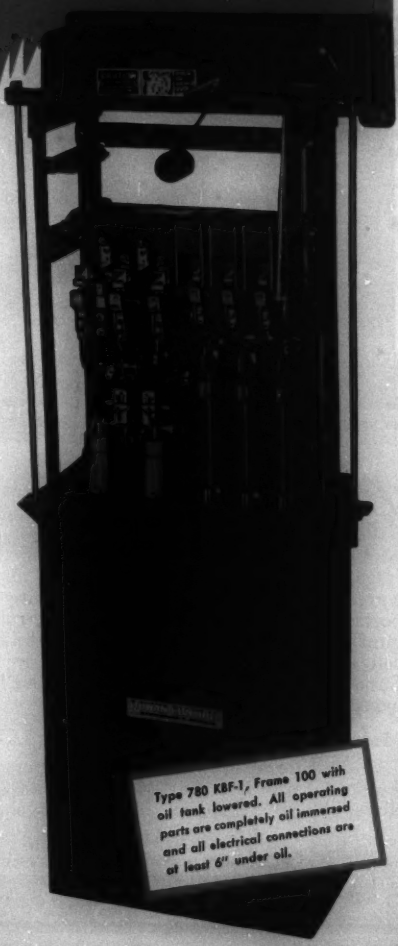
For dependability, use OIL-IMMERSED MOTOR CONTROL in corrosive and hazardous locations

Type 780 KBF-1, Frame 100, closed position. Note provision for straight-thru conduit connections.

FOR use in chemical plants, oil refineries, steel mills and cement plants—in locations where the atmosphere is charged with highly corrosive elements or explosive dust and gases—Rowan engineers designed the 780-1 series of oil immersed motor starters for Class I, Group D locations NEMA Type VIII enclosures.

Rowan type 780 KBF-1 Combination Starters, consist of heavy duty magnetic contactors of the clapper type, giving high speed closing and opening with positive roll and wipe action, magnetic overload relays with inverse time element by means of Rowan AIR SEAL dashpots, each relay is individually tested and calibrated. Safety disconnect switch is of the contactor type with quick make and break mechanism and equipped with Rowan time tested AIR SEAL fuses—top and tank are mechanically interlocked with safety disconnect handle for positive safety with provision for padlocking operating handle in the OFF position.

Complete information available in Bulletin form.

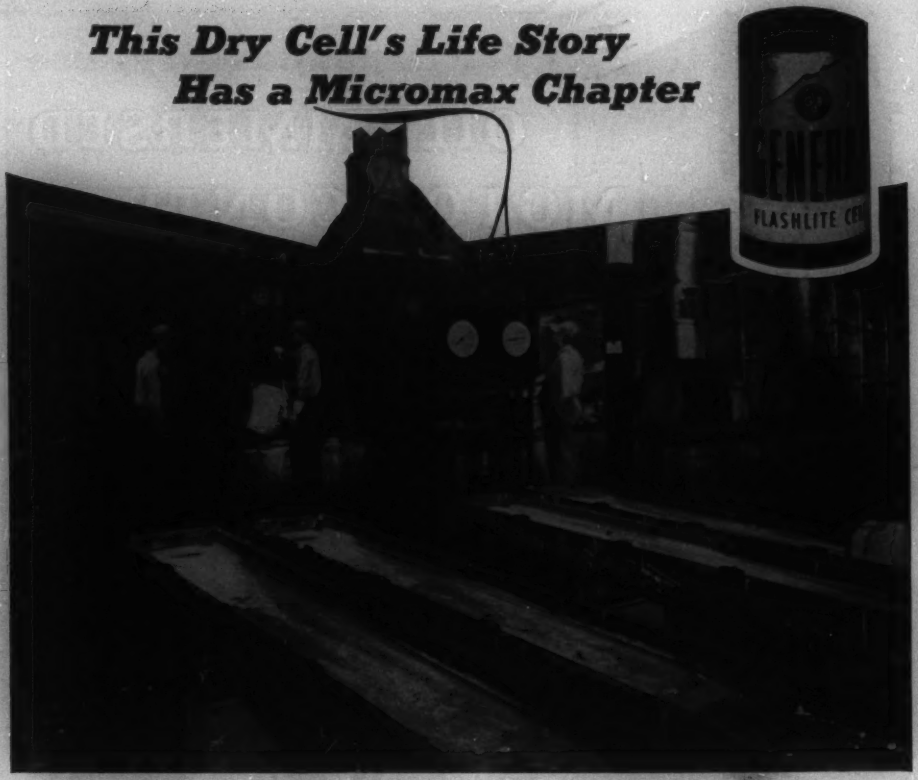


Type 780 KBF-1, Frame 100 with oil tank lowered. All operating parts are completely oil immersed and all electrical connections are at least 6" under oil.

ROWAN CONTROL

THE ROWAN CONTROLLER CO., BALTIMORE, MD.

This Dry Cell's Life Story Has a Micromax Chapter



ZINC "cans" for dry cells take form by hundreds of thousands at the Dubuque, Iowa, plant of General Dry Batteries Inc. And, because the zinc goes through a melting stage, in the 300,000-lb furnace shown above, correct temperature of the melt is quite important. For the molten zinc is cast, rolled, punched into buttons and extruded to the final cell shape, and proper temperature in the furnace can reach right down the line and help many operations which follow.

Measuring Temperature of a Zinc "Lake"

To be sure of fully-dependable temperature facts, General Dry Batteries chose the two Round-Chart Micromax instruments shown above. Measuring furnace temperatures, these instruments are glanced at every few minutes by the melters. The slightest shift in temperature brings prompt action, for the 150-ton "lake" of zinc holds so much heat that it simply cannot be permitted to start swinging or cycling. By reporting all temperature changes accurately and dependably, Micromax enables the "General" melters to hold the great mass constantly in the narrow band which spells maximum production of quality cell-zinc.

Micromax Pyrometers are supplied in strip-chart as well as round-chart models and for any desired form of automatic control. For further information, write to Leeds & Northrup Co., 4962 Stenton Ave., Phila. 44, Pa.

MEASURING INSTRUMENTS · TELEMETERS · AUTOMATIC CONTROLS · HEAT-TREATING FURNACES

LEEDS & NORTHRUP CO.

Jrl. Ad N-33-665(1)

on-the-job proof

where reliability and readability really count

Radio stations can take no chances on "outages"—time off the air is costly. For split-second timing, efficiency, and continuity, all vital operating information must be readily available to the control engineer at a glance.

For these reasons, instruments of unfailing performance and quick readability are a *must*. The Westinghouse instruments at KMOX solved these problems. They also provide co-ordinated styling and smart appearance.

What are YOUR electrical measuring problems?

Would they include—reliable performance . . . styling . . . size . . . readability or different types of service . . . portable . . . switchboard . . . panel . . . recording?

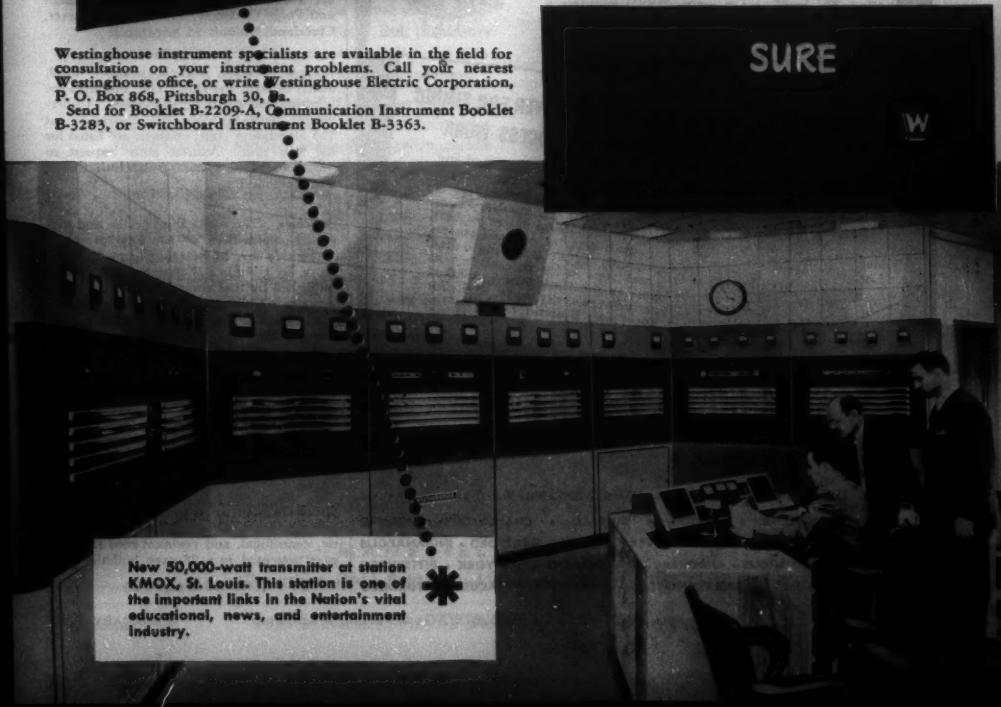
The vast lines of Westinghouse electrical measuring instruments provide you with the answers to all of these problems. Every Westinghouse instrument is backed up by more than 60 years of skill, "know-how", and experience in every field of industry. J-40362

Westinghouse Instruments Also Provide You With

- Dials that *stay* white under all conditions
- Magnets that stay permanent
- Pivots with high shock capacity and low friction
- Springs that remain constant for life
- Quick delivery of more different ratings and types
- Complete Nationwide Service

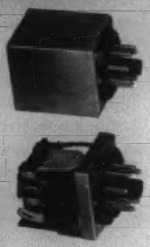
Westinghouse instrument specialists are available in the field for consultation on your instrument problems. Call your nearest Westinghouse office, or write Westinghouse Electric Corporation, P. O. Box 868, Pittsburgh 30, Pa.

Send for Booklet B-2209-A, Communication Instrument Booklet B-3283, or Switchboard Instrument Booklet B-3363.



New 50,000-watt transmitter at station KMOX, St. Louis. This station is one of the important links in the Nation's vital educational, news, and entertainment industry.

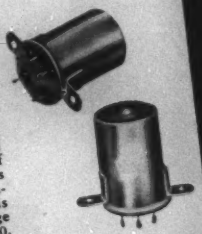
3 IMPORTANT NEW Relay Developments



NEW!...TINY OCTAL BASE RELAYS for AC, DC or half-wave rectified AC

TYPE 118XBX: Available in either open or metal-enclosed types as illustrated, also hermetically sealed. Highly sensitive on DC. DP-DT contacts rated 2 amps. at 115 V. AC. DC operating power is .15 watts with maximum coil resistance of 2,200 ohms. Write for Bulletin 2400.

NEW!...HERMETICALLY SEALED DC RELAYS FOR HIGH-ALTITUDE AVIATION



These little CX3554 Relays are insensitive to humidity changes and capable of operation at 70,000 feet. Features include shock resistance to 50 G's; vibration resistance better than 10 G's; high-speed operation without contact bounce, and reliability over an ambient range of −75° C. to +200° C. SP-DT contacts nominally rated 2 amps. withstand inrushes of 12 amps. at 26.5 V. DC. Coil is rated 26.5 V. DC with operating range of 18/32 V. DC. Write for Bulletin 2410.

NEW!...MONEY-SAVER FOR TIMING CONTINUOUS PROCESS WORK

Besides eliminating the need for numerous cascaded timers, the new Struthers-Dunn DB Timer usually requires much less auxiliary control equipment. An entire process combining many operations can quickly be set up on a single dial. Total time cycle adjustments as well as the timing of individual periods are easily made. Write for DB Timer Bulletin 7110.

Stepless, wide-speed range. Complete timing reliability

STRUTHERS-DUNN

5,348 RELAY TYPES

STRUTHERS-DUNN, INC., 150 N. 13TH ST., PHILADELPHIA 7, PA.

ATLANTA • BALTIMORE • BOSTON • BUFFALO • CHARLOTTE • CHICAGO
CINCINNATI • CLEVELAND • DALLAS • DENVER • DETROIT • HARTFORD • INDIANAPOLIS
LOS ANGELES • MINNEAPOLIS • MONTREAL • NEW ORLEANS • NEW YORK • PITTSBURGH
ROCHESTER • ST. LOUIS • SAN FRANCISCO • SEATTLE • SYRACUSE • TORONTO

(*Continued from page 26A*)

Allis-Chalmers, describes the advantages of their new standardized load center unit substations. Write for bulletin 11B6285A, to Allis-Chalmers Manufacturing Company, South 70th Street, Milwaukee, Wis.

Temperature Instruments for Power Equipment. Revised catalog ND-33-461, published by Leeds and Northrup Company, and directed to those responsible for safe operation of electric power equipment without danger of overheating. Request should be addressed to Leeds and Northrup Company, 4934 Stenton Avenue, Philadelphia 44, Pa.

IRC Advanced Type Resistors. Data on characteristics and specifications of new type BT insulated fixed composition resistors, given in a 12-page illustrated booklet, by the International Resistance Company, 401 N. Broad Street, Philadelphia 8, Pa.

New Locke Catalog Sections. Locke, Inc. has just released two new catalog sections—"Switch and Bus Insulators," and "Fittings for Suspension Insulators." Data tables and NEMA (National Electrical Manufacturer's Association) standards are included. Copies may be obtained by writing to the Merchandising Division, Locke Inc., P. O. Box 57, Baltimore 3, Md.

The Improvement of Metals by Forging. A new 44-page catalog published by the Steel Improvement and Forge Company describes in detail the various types and characteristics of forgings, their designs, and other relative specific information. Copies are available from the Steel Improvement and Forge Company, 969 East 64th Street, Cleveland, Ohio.

Midget Relays. Bulletin number 2100, issued by Struthers-Dunn, Inc., simplifies the selection and use of midget relays. Underwriters approved relay with 15-ampere (at 115 alternating volts) contacts are listed for the first time. Address copy request to Struthers-Dunn, Inc., 150 N. 13th Street, Philadelphia, Pa.

•

Aroclors. The physical properties and suggested applications of Aroclors, produced exclusively by Monsanto Chemical Company, are given in a 27-page booklet recently published by that company. Write to the department of industrial and public relations, Monsanto Chemical Company, St. Louis 4, Mo.

Dow Corning Silicone Notebook. A 31-page booklet concerned with the properties and behavior of the *DC 200* silicone fluids. Titled "DC 200 silicone Fluids, Dow Corning Silicone Notebook, Fluid Series number 3," the notebook may be acquired by writing to Dow Corning Corporation, Midland, Mich.

Speed Measuring Instruments. Description, operation, and selection of chronometric, centrifugal, and resonant reed tachometers presented in a 28-page bulletin pub-

(*Continued on page 44A*)

Specifications cover every question about a pintype insulator

except—

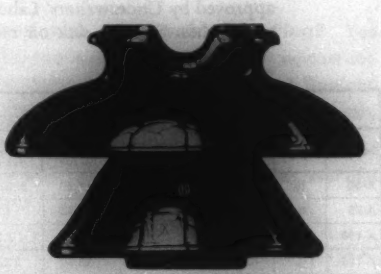
WILL IT BE WORKING TOMORROW?

● All details of a new pintype insulator, fresh from the manufacturer, can be covered by specifications or determined by test. But, insulators don't *stay* new, and the characteristics of a new insulator are only valuable when permanent.

Speaking of permanence, many power companies have records of O-B-insulated lines dating back 30 years or more. Such performance is not exceptional, nor is the end yet in sight.

You can't hold your system together on mere claims for insulator life. With O-B you are dealing entirely within the realm of *facts*. O-B insulators have done and are doing the things that are accepted as standards for insulator durability. When you build with O-B today, you have the highest assurance your insulators will be working tomorrow!

FOR EXAMPLE--This Eastern line was built with O-B pintype insulators in 1914, thirty-five years ago, and is still delivering power to an important class of load. Today, the line would probably be built with O-B Number 31 622 which is fully capable of equalling such performance.



Ohio Brass

MANSFIELD, OHIO

Canadian Ohio Brass Co., Ltd., Niagara Falls, Ont.

O. Z.'s *NEW* ALL-BAKELITE BUSHINGS

BEST BY TEST!

Results of Independent Laboratory Tests*

TORQUE ..... O. Z. *PROVED* 36% *STRONGER* than other bakelite bushings tested.

IMPACT ..... O. Z. *PROVED* 44% *STRONGER* than other bakelite bushings tested.

TENSILE STRENGTH .... O. Z. *PROVED* 112% *STRONGER* than other bakelite bushings tested.

FLAT COMPRESSION .... O. Z. *PROVED* 32% *STRONGER* than other bakelite bushings tested.

Now O. Z. offers you the strongest all-Bakelite insulating bushings made—56% stronger overall than other Bakelite bushings tested in independent laboratory tests (results above)—they bounce like a ball if dropped, won't break even on concrete. And for fast, easy installation and permanent protection, O. Z.'s provide these *plus* features:

- **Smooth, rounded edges completely protect wire insulation during pulling and when in service.**
- **Clean, deep threads let you spin-on the bushing with a twist of the wrist.**
- **Ribbed outer surface provides a grip for slippery hands and permits tapping with screw driver.**

O. Z. Bakelite bushings cost no more than other Bakelite bushings, are fully approved by Underwriters' Laboratories and are available in sizes from ½ inch to 6 inches. Samples sent on request.

**Name and photostatic copy of report will be furnished if you wish.*

NET TRADE PRICES

Cat. No.	Pipe Size	Std. Pkg.	Ctn. Qty.	Lbs. Wt. Per 100	Less Carton Price Per 100	Carton Qty. Price Per 100	Std. Pkg. Price Per 100
A-50	½"	400	100	1½	$ 4.60	$ 3.60	$ 2.90
A-75	¾"	400	100	2	5.75	4.50	3.60
A-100	1"	200	50	3	9.20	7.20	5.75
A-125	1¼"	100	25	4½	26.50	20.30	16.25
A-150	1½"	100	25	6½	30.00	23.40	18.75
A-200	2"	40	20	9	36.00	28.10	22.50
A-250	2½"	20	20	14	58.50	—	36.50
A-300	3"	10	10	18	64.00	—	40.00
A-350	3½"	10	10	22	80.00	—	50.00
A-400	4"	10	10	25	96.00	—	60.00
A-500	5"	5	5	34	210.00	—	130.00
A-600	6"	2	2	45	400.00	—	250.00

CONDUIT FITTINGS • CABLE TERMINATORS
CAST IRON BOXES • GROUNDING DEVICES
SOLDERLESS CONNECTORS • POWER CONNECTORS

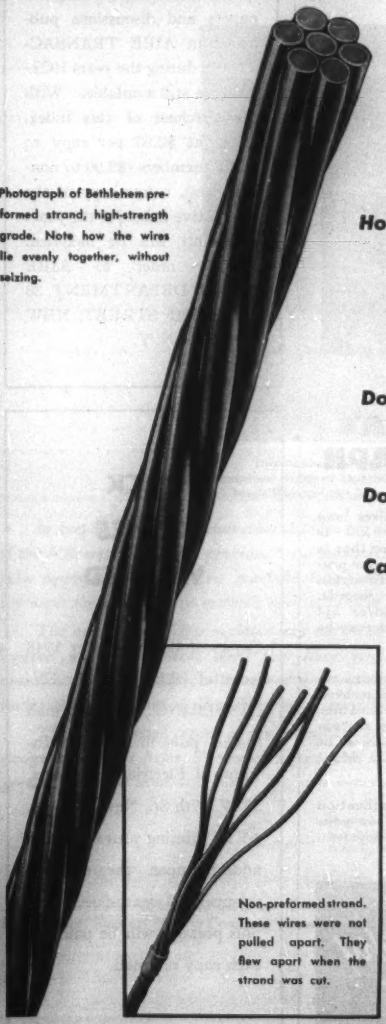
Buy O.Z. and you'll see why Engineers say, "They're OK if they're O.Z."

4820

O.Z. ELECTRICAL MANUFACTURING COMPANY, INC.
262 BOND STREET · BROOKLYN 2, N. Y.

Form-Set Strand

is Bethlehem's *Preformed* Strand



Photograph of Bethlehem preformed strand, high-strength grade. Note how the wires lie evenly together, without seizing.

Non-preformed strand. These wires were not pulled apart. They flew apart when the strand was cut.

Form-Set. A trade name that means just what you'd think. In Bethlehem's Form-Set strand, the "form" of each individual wire has been "set" in advance. In other words, preformed.

How Does It Differ from Ordinary Strand? Since each wire is preshaped to a permanent helix, before being laid together with its neighbors, there is no inner "spring" or tension; the wires cannot fly apart when the strand is cut. Time is saved in the field, and the strand is easier to handle —easier to insert in fittings.

Does It Cost Much Extra? NO! So little more that the extra cost is almost nothing. Most prospective buyers are very surprised—agreeably, we might add.

Does It Come in All Standard Grades and Sizes? Yes —just like conventional, non-preformed strand.

Can It Be Obtained with a Bethanized Coating? Yes indeed—with the ductile zinc armor that guards against corrosion. Form-Set strand is furnished with A-weight, B-weight, or C-weight coating, whichever best meets your requirements.

Let us tell you more about Form-Set; bring you a sample. Its advantages are best appreciated when you see and handle it yourself.

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by
Bethlehem Pacific Coast Steel Corporation
Export Distributor: Bethlehem Steel Export Corporation

BETHLEHEM STEEL

To study TWO *simultaneous* characteristics of *any* device

...use the DUMONT Type 279

Dual-beam CATHODE-RAY OSCILLOGRAPH

● Both the concomitant electrical and/or mechanical characteristics of a piece of equipment may be conveniently examined and recorded with a Du Mont Type 279 Dual-beam Cathode-ray Oscillograph.

For example: You can compare voltage and current, velocity and acceleration, phase relationships, switching time and motor acceleration, velocity and pressure changes within engines, and a multitude of other dual phenomena. Or you can examine a single phenomenon and an expanded, specific portion of it, simultaneously.

This oscillograph utilizes the dual-gun cathode-ray tube to generate and display two entirely separate and independent electron beams, which serve as inertialess, visual indicators. The circuits associated with each gun are also distinct and separate.

Where the application involves long time-intervals, the Type 279 is equipped with a d-c amplifier that is also excellent as an end stage for pre-amplifiers, such as used with strain gauges. For permanent records, Du Mont Types 271-A and/or 314 Oscillograph-record Cameras may be readily applied.

So, if your interest is petroleum research, ballistics, shock absorbers, boiler tubes, control mechanisms, timing devices, or practically any application involving two variables, be sure to investigate this Du Mont instrument.

● Consult us about the application of Du Mont Oscillography to your particular measuring problem.
● Literature on request.

DUMONT *for Oscillography*

ALLEN B. DU MONT LABORATORIES, INC. PASSAIC, N. J.
CABLE ADDRESS: ALBEEDU, NEW YORK, N. Y., U. S. A.

AIEE TRANSACTIONS INDEX

A number of copies of the cumulative index covering the papers and discussions published in AIEE TRANSACTIONS during the years 1922–1938 are still available. With the purchase of this index, prices at $2.00 per copy to AIEE members ($3.00 to non-members), a free copy of the cumulative index for the years 1911–1921 will be included. Address order to AIEE ORDER DEPARTMENT, 33 WEST 39th STREET, NEW YORK 18, N. Y.

BACK COPIES WANTED

Copies of the November 1948 issues of ELECTRICAL ENGINEERING. Please mail (parcel post) to American Institute of Electrical Engineers, 33 W. 39th St., New York 18, N. Y., printing your name and address upon the enclosed wrapper. Twenty-five cents, plus postage, will be paid for each copy returned.

new machines build
new values into
new I-50 meter!

This semi-automatic multi-spindle drilling and tapping machine is one of the many pieces of new equipment designed especially for I-50 production—and designed to insure uniformity of the product. It has 11 heads that perform 27 operations simultaneously, and turn out a completed frame in each cycle.

In keeping with the introduction of the many new design features of the I-50 meter, we have provided new manufacturing facilities—fully equipped with all new machine tools and equipment—that represent the most modern methods and techniques available.

The accuracy and low maintenance costs of the I-50 are further assured by the technical skills that have gone into its various manufacturing steps. Specially trained personnel, precision manufacturing techniques, and rigid quality control are all part of the picture.

They are a vital means of preserving the exceptional qualities designed into this meter. The result is passed on to you in the form of greater sustained accuracy, longer life, and lower maintenance costs.

H. L. Ross

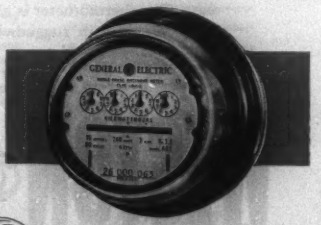
Manager of Manufacturing
Meter and Instrument Divisions
West Lynn, Massachusetts

Type I-50, the first completely new watthour meter in 50 years

Order now from your nearest G-E Representative. Apparatus Department, General Electric Company, Schenectady 5, N. Y.

THESE FEATURES CAN SAVE YOU MONEY

1. Co-ordinated insulation—for better performance under adverse operating conditions.
2. Magnetically suspended rotating element—to do away with bearing maintenance.
3. Braking magnets die-cast in frame—to assure calibration stability.
4. Current coil molded in butyl rubber and potential coil in polyethylene—for greater insulation and stability.
5. One-piece molded "S" base—to minimize corrosion.



GENERAL ELECTRIC

NEW

all-metal WESTON

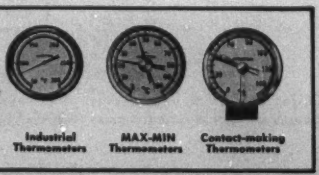
MAGNETIC CONTACT *easily set to make contact at any point on scale*

This new Weston combines the features of an indicating device with the advantages of an alarm or control instrument. A contact arm, mounted as shown above, is easily set to make contact at any temperature on the scale.

A terminal block on the periphery of the case makes electrical connection easy. The thermometer is all-metal, typically WESTON in ruggedness and reliability, with accuracy of ±1% as an indicating thermometer, and ±1½% as a contact making device. It is supplied in two types—for operation on either increasing or decreasing temperatures.

For complete information see your local WESTON representative or write Weston Electrical Instrument Corporation, 617 Frelinghuysen Avenue, Newark 5, New Jersey.

WESTON *Thermometers*



Albany • Atlanta • Boston • Buffalo • Charlotte • Chicago • Cincinnati • Cleveland • Dallas • Denver • Detroit • Houston • Jacksonville • Knoxville • Little Rock • Los Angeles • Meriden • Minneapolis • Newark New Orleans • New York • Philadelphia • Phoenix • Pittsburgh • Rochester • San Francisco • Seattle • St. Louis • Syracuse • Tulsa • In Canada, Northern Electric Co., Ltd., Powerlite Devices, Ltd.

GARDNER TRANSFORMER LEADS ARE INSULATED AND PROTECTED *With* NATVAR 400

Gardner distribution transformers are built in the new, modern factory building of the Gardner Electric Manufacturing Company, Inc. in Emeryville, California, "close to the center of the most rapidly growing part of the United States."

It is this rapid growth that taxes distribution facilities to the limit, and places a premium on the ability of the equipment to handle "temporary" overloads far in excess of rated capacity. Gardner transformers are now being used by a majority of the principal Power Companies in this Pacific Coast Area.

Core and coil assembly of a Gardner 37.5 kva distribution transformer, 2400-120/240 volts, single phase, 60 cycle. Both high voltage leads from coil to terminal board and low voltage leads are insulated and protected by Natvar 400 Extruded Vinyl Tubing.

Natvar 400 Extruded Vinyl Tubing, approved for 105°F is used to insulate and protect leads, because it meets operating temperature requirements, and in addition, has uniformly superior resistance to oil.

Prompt deliveries can be made either from a nearby wholesaler's stock or direct from our own. Full Underwriters report on request.

Natvar

Natvar Products

- Varnished cambric—straight cut and bias
- Varnished cable tape
- Varnished canvas
- Varnished duck
- Varnished silk
- Varnished special rayon
- Varnished Fiberglas cloth
- Silicone coated Fiberglas
- Varnished papers
- Slot insulation
- Varnished tubings and sleevings
- Varnished identification markers
- Lacquered tubings and sleevings
- Extruded vinyl tubing and tape
- Extruded vinyl identification markers

Ask for Catalog No. 21

THE NATIONAL VARNISHED PRODUCTS Corporation

TELEPHONE RAHWAY 7-2171 — CABLE ADDRESS NATVAR: RAHWAY, N. J.

203 RANDOLPH AVENUE ★ WOODBRIDGE NEW JERSEY

WHEN THIS NEW INDIANA PERMANENT MAGNET

REPLACED THIS OLD ONE

A BETTER SPEEDOMETER WAS BORN

New King-Seeley speedometer

★

Indiana—world's largest exclusive producer of permanent magnets—is the *only* manufacturer furnishing all commercial grades of permanent magnet alloys. Most commonly used are:

CAST:
Alnico I, II, III, IV, V, VI, and XII; Indalloy; Cunico; Cobalt.
SINTERED:
Alnico II, IV, V; Indalloy; Vectolite.
DUCTILE:
Cunico; Cunife I and II; Silmanal.
FORMED:
Chrome; Cobalt; Tungsten.

Ask for free Book No. 4-A2—our new permanent magnet engineering manual. A note on your company letterhead will bring a copy to your desk.

40 YEARS OF BETTER PERMANENT MAGNETS

★

Indiana's experience brings Better Designs, Lower Costs

Recently our engineers, working with those of King-Seeley Corp., helped design an entirely new permanent magnet for a greatly improved speedometer. This *Indiana* magnet, made of Cunife, weighs *one third less* than the previous magnet, yet has *30% more energy.* It reduces bearing load by 50%, and is 750% more stable—is *far* more resistant to shock, temperature change, stray magnetic fields. And it *costs less.*

WE MAY HAVE *YOUR* ANSWER, TOO

For four decades, the pace-setting design techniques at *Indiana* have made possible new and better permanent magnets. This "packaged energy" improves performance, adds new functions, *saves money* in countless different products . . . as mechanical force in holding and separating devices . . . for changing electrical energy to mechanical motion and vice versa . . . for changing the apparent characteristics of materials. *Indiana* offers you the experience and know-how of more than 30,000 different applications. Let's get our engineers together on *your* problem. Write *today.*

THE INDIANA STEEL PRODUCTS COMPANY

PRODUCERS OF "PACKAGED ENERGY"
6 NORTH MICHIGAN AVENUE • CHICAGO 2, ILL.

SPECIALISTS IN PERMANENT MAGNETS SINCE 1908
PLANTS: VALPARAISO, INDIANA • CHAUNCEY, N. Y.

Eliminate MAINTENANCE *Hazards* AND *Headaches* DUE TO FAULTY INSULATORS!

Switch to

"PORCELAIN PRODUCTS" PINTYPES *They're Better!*

No doubt about it. Emergency crews stay home, power stays on when "Porcelain Products" Pintypes take over. They're made tough, with compression glaze and withstand the hazards of heat and cold, heavy wind and ice loads. They're better because rigid manufacturing standards and testing of every insulator assure perfect performance. Whatever your requirements, there's a "Porcelain Products" Pintype tailor-made for the job. On your next order specify "Porcelain Products"—and see what a maintenance load you take off your linemen. Get your copy of new Catalog 10-A showing other "Porcelain Products" High Voltage Insulators and accessories.

Porcelain Products, Inc.

PARKERSBURG, WEST VIRGINIA

Special ELECTRICAL PORCELAIN

. . . has long been a PINCO specialty. We offer . . .

- Expert specialized engineering help in the design and adaptation of porcelain for *new* dielectric uses.
- A complete laboratory service for development, experimentation and testing.
- Facilities for successful, economical production of electrical porcelain in unusual shapes and sizes.
- PINCO "Wet Plastic Process" Porcelain . . . unexcelled in electrical and mechanical strength.

Put your special porcelain problems up to PINCO. We may have research and experimental data which will speed the solution. Write . . .

The Porcelain Insulator Corporation

763 MAIN STREET · LIMA, N.Y.

PINCO INSULATORS

You CAN Split a Volt!

with this Voltage Regulator

No testing laboratory is complete without an Acme Electric Voltrol. Manually operated it provides stepless voltage regulation from 0 to 135 volts. Regulation is accurate to within 4/10 volt adjustment. Operates from 110/115 volt, 60 cycle primary circuit, output voltage is practically independent of the load. Voltrol is available in portable type (shown above) and panel board mounting design.

Write for Bulletin S-172.

ACME ELECTRIC CORPORATION

222 WATER STREET ◆ ◆ ◆ CUBA, N. Y.

Acme Electric

AIEE REPORTS

(No charge for copies)

These publications are proposals for new standards or test codes, or revisions of present publications, which are in the formative stage.

They are made available, without cost, so that all interested individuals may obtain them for study, and comment, thereby supplying practical experience in their use before submission for adoption.

LATEST

551 Master Test Code for Temperature Measurement (Oct. 1948)

---

6 Pool Cathode Mercury-Arc Power Converters (June 1946)

20A Low-Voltage Air Circuit Breakers (Dec. 1946)

24 Protector Tubes (July 1940)

43 Insulation Resistance Testing of A-C Rotating Machinery (Dec. 1946)

502 Test Code for Single-Phase Motors (Nov. 1941)

550 Master Test Code for Resistance Measurement (Sept. 1947)

600 Recommended Specification for Speed Governing of Prime Movers Intended to Drive Electric Generators (July 1944)

750 Aircraft Electric System Guide (July 1947)

800 Test Code for Direct-Current Aircraft Machines (March 1947)

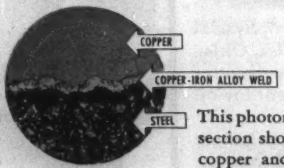
American Institute of Electrical Engineers—33 W. 39th St., New York 18

proved -a million times!

According to the aerodynamic theories of a few years ago, it was impossible for the bumble bee to fly. Its body was too heavy for its wings. Despite this handicap, bumble bees by the millions refused to be grounded.

Before 1915, copper and steel had never been successfully integrated and doubters said that a practical method would never be found. The different melting points and the varying expansion rates of these two metals had presented too much of a problem. Then Copperweld Steel Company developed the Molten-Welding Process, and presented industry with the first successful copper-covered steel wire. Today, the millions of miles of Copperweld Wire in service have proved that Copperweld provides the highest standards of efficiency at lowest annual cost.

In the Molten-Welding Process, molten copper is poured around a heated alloy steel billet under carefully controlled temperatures and casting conditions.



This photomicrograph of the weld section shows how the crystals of copper and steel form a permanent and continuous weld. The perfect interlocking of these two metals, accomplished only by Molten-Welding, provides rugged strength, high conductivity, rust-resistance and long life.

Tensile strengths up to 180,000 pounds per square inch are attained with the special alloy steel used in Copperweld Wires. And these strengths are permanent because the steel is always protected by a heavy copper covering of uniform thickness.

When your specifications or purchase orders call for Copperweld, make certain that you get Copperweld quality by actually seeing the name "Copperweld" on the product itself or on the tag accompanying every coil and reel.

COPPERWELD STEEL COMPANY • Glassport, Pa.

Sales Offices In Principal Cities

Copperweld TRADE MARK PRODUCTS

• POWER CONDUCTORS • GUY & MESSENGER STRAND • OVERHEAD GROUND WIRE • GROUND RODS & CLAMPS • COUNTERPOISE WIRE • TELEPHONE LINE WIRE • TELEPHONE DROP WIRE • WEATHERPROOF WIRE • SIGNAL LINE WIRE • SIGNAL BONDS • INSULATOR TIES • NAILS & STAPLES • FENCE & BARBED WIRE

They Discover Oil with Aid of ADC Transformers

THE STORY OF

Century

SEISMIC EQUIPMENT and OIL PROSPECTING

The Century Geophysical Corporation of Tulsa, Okla., is a prominent manufacturer of seismic equipment for oil prospecting.

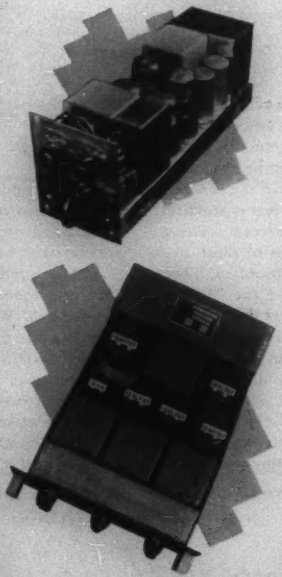
With Century equipment Geophysicists and Geologists determine the general location of new oil fields by charting fault patterns, salt domes, and deep seated limestone beds, all of which is done on a principle of echo.

These techniques require extreme accuracy so that comparison of soundings will reveal slight contour changes at depths of up to three miles.

That **ADC** was selected by Century to manufacture transformers and inductors for their special electronic components is another evidence that ***"Audio Develops the Finest."***

HOW ADC TRANSFORMERS HELP DISCOVER OIL...

Heart of the geophysical unit for detecting oil deposits is the seismic equipment in the recording truck. Century called on **ADC** to work out the complicated specifications on transformers and inductors for seismograph amplifier, etc., to obtain the extreme accuracy, durability and dependability they require.



ADC **Audio DEVELOPMENT CO**
Audio Develops the Finest
2853 13th AVE. SOUTH · MINNEAPOLIS 7, MINN.

EXPERIENCED SUPERVISORY ENGINEERS

☆ ☆ ☆ ☆

SOUTH AMERICA

A large integrated oil company needs experienced supervisory and staff engineers of the following catagories in Venezuela.

SENIOR AND SUPERVISORY ENGINEERS

10 to 20 years rounded experience in Civil, Electrical or Mechanical Engineering to perform staff engineering studies or to supervise design, estimating, and construction of townsites, public utilities and oil field industrial installations.

☆ ☆ ☆ ☆

Retirement plan, paid vacation, Career opportunity

Address: Box 731
ELECTRICAL ENGINEERING
500 Fifth Ave., New York 18, N.Y.

The most difficult Insulating problems are solved with

SINCE 1919 MYCALEX THE INSULATOR

LOW LOSS HIGH FREQUENCY INSULATION TO MEET HIGH MECHANICAL AND ELECTRICAL SPECIFICATIONS WITH OR WITHOUT METAL INSERTS

MYCALEX "410"
Molded to high precision
With or without metal inserts

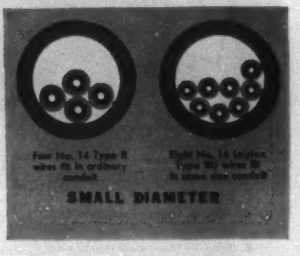
MYCALEX "400"
Sheet Stock — Rod Stock
We have fabricating facilities

MYCALEX "K"
High dielectric Constant

Prompt Service
Our engineers cooperate in design and application

MYCALEX CORPORATION OF AMERICA
Owners of "MYCALEX" Patents
62 CLIFTON BOULEVARD
CLIFTON, N. J.

United States Rubber Company's unique dip or pass method applies the insulation in *perfectly uniform* layers. Moreover, this insulation is 90% pure rubber, unmilled in order to preserve its high physical qualities. The extra strength of natural rubber, plus a strong fibrous cover and special finish gives extra protection against mishandling, sharp bends, moisture and flame.



Yet, despite the unusual safety features of Laytex RU, this wire is smaller in diameter and lighter in weight than any other natural rubber covered wire on the market. Not only is Laytex unsurpassed in physical and electrical qualities, but it will also permit *more wires per conduit.*

The tensile strength of Laytex RU is over 7 times that of Type R, and twice that of Type T. Its insulation resistance constant is over 3 times that of Type T, and over 8 times that of Type R. Add all these advantages up, and no wonder Laytex RU is the finest building wire on the market today.

U. S. Laytex RU is labeled by the Underwriters' Laboratories and listed in the National Electrical Code as an all-purpose wire. Send for a sample and free booklet. Write Wire and Cable Department, United States Rubber Company, 1230 Avenue of the Americas, New York 20, N. Y.

**Reg. U. S. Pat. Off.*

"This Wire's got Safety and long Life...It's *Laytex* RU."

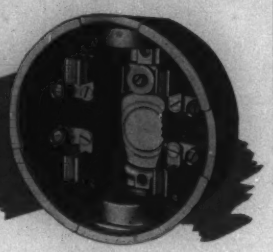
So says Mr. USRUBBY, the Wire Engineer. And you, Mr. Engineer, will agree with him. For when you specify U. S. Laytex RU, you are getting a wire that will not suffer from the dangerous thin spots formed on ordinary wires. Why? Because

RU wiring with RU?

A PRODUCT OF
U.S. RUBBER
SERVING THROUGH SCIENCE
UNITED STATES RUBBER COMPANY

NEW STANDARDIZED DEEP METER SOCKET

Low price plus these advantages...



1. Additional wiring space for more liberally rated conductors
2. Greater ease of connecting larger conductors
3. Increased current-carrying capacity
4. New and improved all-welded, one-piece, stainless steel ring
5. Snap-action, quick-hitch ring that requires no tools for installation
6. Bonderized plus baked-on aluminum paint for increased corrosion resistance and longer life
7. Two-way ($3.00 list) three-way ($3.85 list), subject to change without notice.

This new type R-1 four-terminal standardized socket covers with one catalog item the widest practicable range of applications and ratings for single-phase metering. It reduces the number of items to be stocked, increases interchangeability, and provides for future growth.

Detailed specifications and prices are available from your nearest G.E. representative. Consult him today, or write for Bulletin GEA-5147. *Apparatus Dept., General Electric Company, Schenectady 5, N. Y.*

GENERAL ELECTRIC

661-48

the first line of standard electronic voltage regulators

Only Sorensen electronic voltage regulators offer as much as 0.1% regulation accuracy under SIMULTANEOUS line and load changes.

SIX IMPORTANT SORENSEN FEATURES:

1. Precise regulation accuracy;
2. Excellent wave form;
3. Output regulation over wide input voltage range;
4. Fast recovery time;
5. Adjustable output voltage, that once set, remains constant;
6. Insensitivity to line frequency fluctuations between 50 and 60 cycles.

The Sorensen Catalog contains complete specifications on standard voltage regulators and nobatrons. It will be sent to you upon request.

SORENSEN and company, inc.

375 fairfield avenue, stamford, connecticut

(*Continued from page 30A*)

lished by the James G. Biddle Company. Write for bulletin 35-7 to James Biddle Company, 1316 Arch Street, Philadelphia 7, Pa.

New General Switch Catalog. A recently issued 68-page catalog published by the General Switch Corporation gives full details of their complete line of switches. Distribution of the booklet is confined to persons engaged in specifying electrical equipment. Requests should be addressed to General Switch Corporation, 44 Roebling Street, Brooklyn 11, N. Y.

NEW PRODUCTS • • •

Magnet Charger. The Model 107 Magnet Charger, manufactured by Radio Frequency Laboratories, Inc., Boonton, N. J., contains a 100-microfarad capacitor, an associated 500 volt power pack, and a current transformer through which the capacitor bank is discharged in .002 second. The transformer secondary is connected to a charging bar, which is arranged for convenient association with the magnet for induction of the charging magnetic flux, in excess of 15,000 amperes peak value. This peak current can be increased by the Model 206 Booster Unit. The charger is portable, weighing 75 pounds, and can be connected to any 110/120-volt, 50/60-cycle a-c outlet.

Polyethylene Covered Wire. ReLene weatherproof wire, covered with polyethylene, has been added to the line and cable products of Rome Cable Corporation, Rome, N. Y. The new wire is moisture resistant, lighter weight, and of smaller diameter, has resistance to abrasion, sunlight, and other weather hazards. Because it is not the conventional fibrous braided type, longer spans for the same loading conditions are possible.

Recording Vibrometer. General Electric's general engineering and consulting laboratory has developed a new recording vibrometer which measures and records frequency, displacement, and wave shape of mechanical vibration. Built to operate either when mounted on a fixed base or held in the hands (the vibrometer weighs only seven pounds), the instrument is intended for application in testing all types of reciprocating and rotating machinery within a vibration frequency range of 10 to 120 cycles per second. It records both steady-state and transient vibrations. Both the chart speed and the interval between timing marks are governed by a synchronous motor operated from a 115-volt, 60-cycle power supply. Further information may be obtained by writing for bulletin GEC-310, to the General Electric Company, Schenectady 5, N. Y.

"Multipath" Resistor. A new type of resistor, "Multipath," based on the use of slit and formed alloy sheet, is now being produced in the United States by the Exmet Electrical Corporation in conjunction with the National Lock Washer Company, under

(*Continued on page 48A*)

SPRAGUE

PIONEERS OF ELECTRIC AND ELECTRONIC PROGRESS

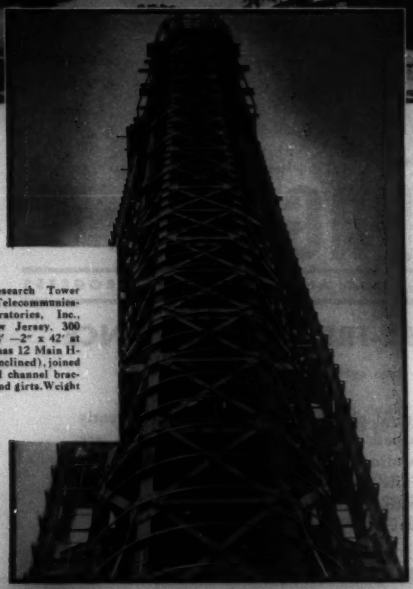
BUILT FOR LONG, TROUBLE-FREE PERFORMANCE UP TO 450 VOLTS AT 85°C.

These sturdy little dry electrolytics have what it takes to match the toughest capacitor assignments in television and other exacting equipment where the use of ordinary components may only be inviting trouble. They're compact, easy to mount. They'll withstand plenty of heat. Thanks to a recently developed processing technique, they are outstandingly stable, even after extended shelf life. In every respect, they are designed for better-than-average service on tougher-than-average jobs.

SPRAGUE ELECTRIC COMPANY, NORTH ADAMS, MASSACHUSETTS

Experimental Talking Tower

FABRICATED AND ERECTED BY AMERICAN BRIDGE COMPANY



2-story Research Tower
Federal Telecommunica-
ons Laboratories, Inc.,
utley, New Jersey. 300
et high, 38' –2" x 42' at
e base, it has 12 Main H-
olumns (4 inclined), joined
y angle and channel brac-
g, beams and girts. Weight
760 tons.

View showing completed project. Laboratory buildings were erected for Federal Telecommunications Laboratories, Inc. Buildings 1 and 2 (in background) Louis S. Weeks, Architect—George A. Fuller, General Contractor. Buildings 3 and 4 and Tower (in the foreground) Giffels and Vallet, Inc., Engineers—L. Rossetti, Architect—George A. Fuller, General Contractor. All structural steel fabricated and erected by American Bridge Company.

● Improved television. Multi-channel communication links. FM mobile communications systems. Radar aids to aerial navigation. These are a few of the projects already begun in the research tower and laboratory buildings which American Bridge Company fabricated and erected for subsidiaries of International Telephone and Telegraph Corporation in Nutley, New Jersey.

The same care, the same service, the same knowledge American Bridge used on this and many other projects are available to you whatever the size or complexity of your structural or erection requirement.

AMERICAN BRIDGE COMPANY

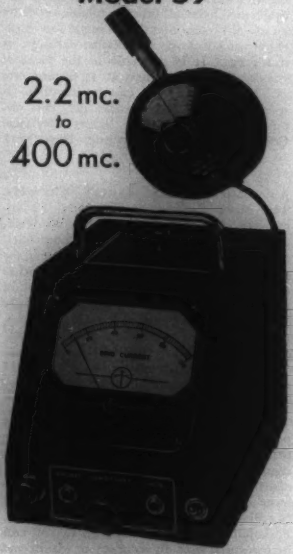
General Offices: Frick Building, Pittsburgh, Pa.

Contracting Offices in: BALTIMORE · BOSTON · CHICAGO · CINCINNATI · CLEVELAND
DENVER · DETROIT · DULUTH · MINNEAPOLIS · NEW YORK · PHILADELPHIA · ST. LOUIS
COLUMBIA STEEL COMPANY, San Francisco, Pacific Coast Distributors
UNITED STATES STEEL EXPORT COMPANY, NEW YORK

USS **AMERICAN BRIDGE**

MEASUREMENTS CORPORATION
Model 59

2.2 mc. to 400 mc.



MEGACYCLE METER

Radio's newest, multi-purpose instrument consisting of a grid-dip oscillator connected to its power supply by a flexible cord.

Check these applications:

- For determining the resonant frequency of tuned circuits, antennas, transmission lines, by-pass condensers, chokes, coils.
- For measuring capacitance, inductance, Q, mutual inductance.
- For preliminary tracking and alignment of receivers.
- As an auxiliary signal generator; modulated or unmodulated.
- For antenna tuning and transmitter neutralizing, power off.
- For locating parasitic circuits and spurious resonances.
- As a low sensitivity receiver for signal tracing.

MANUFACTURERS OF
Standard Signal Generators
Pulse Generators
FM Signal Generators
Square Wave Generators
Vacuum Tube Voltmeters
UHF Radio Noise & Field Strength Meters
Capacity Bridges
Megohm Meters
Phase Sequence Indicators
Television and FM Test Equipment

SPECIFICATIONS:

Power Unit: 5½" wide; 6⅛" high; 7½" deep. **Oscillator Unit:** 3¾" diameter; 2" deep.

FREQUENCY: 2.2 mc. to 400 mc.; seven plug-in coils.

MODULATION: CW or 120 cycles; or external.

POWER SUPPLY: 110-120 volts, 50-60 cycles; 20 watts.

MEASUREMENTS CORPORATION
BOONTON NEW JERSEY

putting the finger on power control problems

If you're concerned with problems involving the control of electrical power, you'll do well to get acquainted with Power Equipment Company. For PEco engineers have specialized in controlled rectifiers exclusively over the past 14 years . . . have pioneered in the development of a multitude of circuits aimed at simplification of equipment, reduction in size and weight, lower maintenance cost, greater accuracy of control, automatic operation, and longer rectifier life.

Take PEC 272, the rectifier power supply unit illustrated, for example: It's portable . . . designed for quick, convenient use when and where you need it. Provides unusual flexibility of testing power. Eliminates necessity of maintaining banks of batteries. Gives you accurate control of filtered, closely regulated power for a wide range of applications. And it incorporates the specialized functional design features and precise electrical characteristics achieved by PEco engineers in many other unusual types of equipments. Write for Bulletin No. 848.

POWER EQUIPMENT Company

Battery Chargers ☆ Battery Eliminators ☆ D.C. Power Supply Units ☆ Regulated Exciters ☆ Voltage Stabilizers ☆ and other Special Communications Equipment

55 ANTOINETTE STREET DETROIT 2, MICHIGAN

SORGEL AIR-COOLED TRANSFORMERS

Prompt Deliveries of Dry-Type Transformers

50 Kv-a. and smaller usually from stock

1/4 Kv-a. Single Phase 460/230 to 115 volt

A size and type for every purpose.
1/4 Kv-a. to 2000 Kv-a.
All voltages.
Single phase and 3-phase.

3 Kv-a. 3-phase Wall Mounting Type

Liberal Design.

Steel Encased.

Solderless Terminals.

Connection Compartment.

Quiet Operation.
Low Temperature.
High Efficiency.
Long Life.
Priced Right.

100 Kv-a. Single Phase Floor Mounting Type

SORGEL ELECTRIC CO. 846 W. National Ave., Milwaukee 4, Wis.
Pioneers in the development and manufacturing of Air-Cooled Transformers

(Continued from page 44A)

license covering a number of patents of British origin, as the resistor was originally developed within the British Admiralty during the war. The new-type resistor is distinguished from all other available types by its use of precision-cut sheet metal for resistance instead of wires, ribbons, castings, or stampings. It is available in the form of standardized units, rated 20 to 80 amperes (4.5 to 0.3 ohms), but can be supplied in special design. Information may be obtained by writing to the Exmet Electrical Corporation, 59 Park Avenue, New York 16, N. Y.

Automatic Floating Battery Chargers. The Power Equipment Company, 55 Antoinette Street, Detroit 2, Mich., has developed a new line of electronically controlled and regulated floating battery chargers, for power stations, communications, and other applications requiring accurate control of floating voltage. The chargers are fully automatic, have constant potential output, and are designed to maintain floating charge on the battery group to within plus or minus one per cent. Regulation is independent of a-c line voltage and frequency fluctuations.

Transformer Turn Ratio Test Set. A portable, direct-reading instrument for measuring turn ratio in power transformers, designed for use on all types and sizes of power, distribution and auto transformers in common use, has been developed by the James G. Biddle Company, 1316 Arch Street, Philadelphia 7, Pa. Ratios up to 130 can be measured with an accuracy to within one part in 1,000. It is intended for use both in the shop and in the field.

Kollsman Synchrotel. A new version of the Kollsman Synchrotel increases electrical output by 500 per cent, and decreases the volume to 1/3 of the former unit. This reduced volume also reduces the price of the standard instrument. The new Synchrotel functions as an inductive electric pickoff wherever driving torque is so small that a conventional synchro cannot be used. Its lightweight rotor, 3/4 gram, makes it useful where very high accelerations and rapid oscillations are to be measured. A descriptive pamphlet concerning the instrument may be obtained by writing to the Kollsman Instrument Division of Square D Company, Elmhurst, N. Y.

Current Transformers. Model 313 "Donut" type instrument current transformers, manufactured by Associated Research, Inc., 231 S. Green Street, Chicago 7, Ill., are of the insert primary type, insulated for 4,500 alternating volts and can be used on 25 to 133 cycles. The transformers are available in ratios from 25/5 to 1000/5 amperes and in multirange combinations with single primary and tapped secondaries so as to provide several ranges without making elaborate circuit changes necessary.

Electric Contacts. Made from copper tungsten by the powder metallurgy process, the Gibsiloy *UW6* electric contact, manufactured by the Gibson Electric Company, is capable of interrupting very heavy currents with minimum erosion. For information contact the Gibson Electric Co., 8350 Frankstown Avenue, Pittsburgh 21, Pa.

OHMITE THIN RESISTORS

VITREOUS-ENAMEL COVERING
Winding is rigidly held in place and protected from damage by Ohmite special vitreous enamel.

EVEN, UNIFORM WINDING
"Hot spots" and resultant failures are prevented by the resistance winding's unsurpassed uniformity.

STRONG, CERAMIC CORE
Unaffected by cold, heat, fumes, or high humidity, its core provides a strong base for winding.

FIVE WATTAGE SIZES
Lengths range from 1¼ inch to 6 inches, corresponding to ratings of 30 to 75 watts.

INTEGRAL MOUNTING BRACKETS
Distribute heat more evenly throughout resistor and conduct heat away quickly.

...PACK HIGHER WATTAGE INTO LESS SPACE

Because of their compact design, Ohmite Thin Type Resistors have a higher wattage rating per unit of space. They provide all the time-proven superiority of conventional Ohmite vitreous-enamel resistors—giving you a compact unit you can depend upon. Available in four types—all only ¼ inch thick by ½ inch wide—in five lengths and a wide range of resistance values.

Send for Bulletin No. 138

OHMITE MANUFACTURING CO.
4801 W. Fleurnoy St., Chicago 44, Ill.

Be Right with

OHMITE
RHEOSTATS • RESISTORS • TAP SWITCHES

For those who want better prints

faster

Model 21 Bruning Whiteprinter for moderate print production.

BRUNING BW WHITEPRINTERS

There is a Bruning Whiteprinter to meet the requirements of any drafting or engineering department . . . and every one of them is designed to make perfect prints of your tracings . . . fast. In seconds after you turn on a Bruning machine you are producing copies that are tops in legibility. There is no time lost waiting for prints to dry . . . BW prints are ready for instant use as fast as they come from the machine. There is no time spent making negatives . . . BW machines make clear, sharp positive prints (black on white) directly from any copy that is drawn, typed or printed on a translucent material.

If you need sharp duplicate prints . . . big or small . . . on paper, card, film, or cloth, it will pay you to investigate Bruning Whiteprinters . . . the last word in efficient and accurate duplication of engineering and/or office forms.

CHECK THESE BW ADVANTAGES

Just plug in: Bruning Whiteprinters plug into standard 110 or 220 outlets, depending upon the size of the machine. No special wiring required.

No vents or exhaust fans: The BW process is completely odorless . . . can be performed anywhere in the office without the slightest offense.

No plumbing connections: There are no pipes to connect, no water to supply or drain away. Nothing to anchor the machine to one spot.

Wide variety of prints: BW prints can be made on light, medium or card weight paper with black, blue, red or brown lines. Also on tinted stocks, transparent paper, film and cloth.

A 1001 uses: A BW unit can reproduce a letter, invoice, chart, financial report or other document as easily and quickly as it makes perfect prints from engineering drawings. It is truly a company-wide machine.

Other Bruning products you should know about

Drafting Machines - Drafting Room Furniture - Slide Rules - Erasing Machines - Surveying Instruments Tracing Papers and many others.

Send today **for full information.**

Let us send you a file of descriptive literature on Bruning Whiteprinters and BW materials. There is no obligation. It would be helpful to know approximately how many copies you plan to make a day and their average size.

Charles Bruning Company, Inc.

Since 1897

4714-42 West Montrose Avenue, Chicago 41, Ill.

New York - Chicago - Los Angeles - And 11 Other Cities

ELECTRON TUBE REPORTS

Electron Tubes for Instrumentation and Industrial Use

This publication includes papers and discussions presented at the AIEE Conference on Electron Tubes for Instrumentation and Industrial Use, sponsored by the AIEE joint subcommittee on electronic instruments, held in Philadelphia, Pa., March 29–30, 1948.

Price: $3.00

($1.50 to AIEE Members)

✦

Electron Tube Survey

About 900 electron tube using organizations were sent questionnaires early in 1947 in order to ascertain the need for improved electron tubes. The "Report on Electron Tube Survey of Instrument Manufacturers and Laboratories," prepared by the AIEE joint subcommittee an electronic instruments, includes the background of the survey, a copy of the questionnaire, and the results which have been derived from the survey. This survey report stimulated much discussion on the improvement of electron tubes for instrumentation and industrial use, and it subsequently became the central subject at the Philadelphia Conference.

Price: $2.00

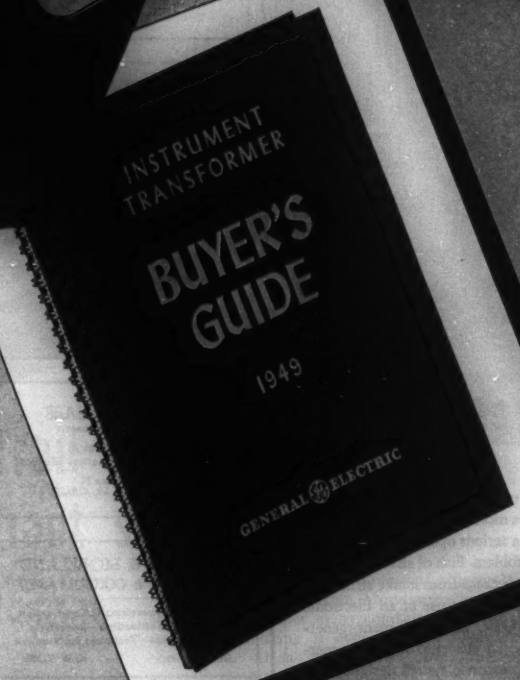
($1.00 to AIEE Members)

✦

COMBINATION OFFER:

Both of these electron tube reports are available in a special combination offer of $4.00 ($2.00 to AIEE Members). Orders should be directed to the AIEE ORDER DEPARTMENT, 33 West 39th Street, New York 18, N. Y.

INSTRUMENT TRANSFORMERS



FOR your convenience General Electric has just published a new Buyer's Guide on instrument transformers. This is a sequel to earlier guides which have proved so popular in the past. It contains up-to-date information on 107 types of G-E instrument transformers for both indoor and outdoor use.

In addition to the clear, detailed illustrations on each page, you will find information on prices, ratings, and ASA accuracy classifications. All this has been combined to provide you with a handy digest of G-E Standard Transformers.

References are provided on each page to help you order supplementary bulletins containing more technical descriptions. These are free, as is the Buyer's Guide itself. Fill in coupon to get yours now. *Apparatus Dept., General Electric, Schenectady 5, N. Y.*

CLIP AND MAIL THIS COUPON TODAY

YES I need a copy of the new "Buyer's Guide" (GEA-4626) to help me in the selection of instrument transformers.

Name .....

Company ..... Title .....

Address .....

City ..... State .....

MAIL TO: Apparatus Dept., General Electric Co., Section C 604-22, Schenectady 5, N. Y.

STOP FISH

BY ELECTRONICS

This patented fish control method employs modern electronics in overcoming a serious operating and maintenance problem. Fish of all sizes are kept at a *safe distance* from intake structures, or screens, by the use of an Electronic Control Unit. This equipment, generating special electrical impulses, energizes an electrode system designed and engineered for your particular fish control problem.

The Burkey Electric Fish Screen has been thoroughly proven through years of service in Condensing Water Intakes, Hydroelectric Plants, Water Systems and Industrial Pumping Installations. DOES NOT STUN OR KILL FISH.

Recommended by State Conservation Officials

Free literature and quotations upon request

Electric Fish Screen Co.

1130 No. Poinsettia Place
Hollywood 46, California

Professional Engineering Directory

Professional Engineering Directory Card 1" x 2" 6 times $60.00 12 times $90.00

BLACK & VEATCH
Consulting Engineers
Water, Steam and Electric Power Investigations, Design, Supervision of Constructions, Valuation and Tests
4706 Broadway KANSAS CITY, MO.

Roland R. Miner, Member AIEE — Lottye K. Miner, Associate AIEE
MINER & MINER
Consulting Engineer
Design-Development-Investigations
Valuations
Experience in the utility, industrial and appliance manufacturing fields
1825 Tenth Avenue Greeley, Colorado

¶ *PROFESSIONAL SERVICES over a wide range are offered by these cardholders.*

¶ *CONSULT THE DIRECTORY when in need of specialized engineering advice.*

CONSULT
Z. H. POLACHEK
Reg. Patent Attorney
1234 BROADWAY
(At 31st St.)
New York 1, N. Y.
PHONE: LO. 5-3088

PATENTS TRADEMARKS
PETER FRIES, JR., E.E.
Registered Patent Attorney
110 East 42nd Street
New York 17, N. Y.
Telephone: MUrray Hill 8-4476

SANDERSON & PORTER
ENGINEERS
AND
CONSTRUCTORS
NEW YORK CHICAGO
SAN FRANCISCO LOS ANGELES

STANLEY B. HARE
Consulting Engineer
Electrical Design
Commercial and Special Motors
2881 Camulos Pl.
LOS ANGELES 23, CALIF.

SARGENT & LUNDY
ENGINEERS
140 South Dearborn Street
CHICAGO, ILLINOIS

JACKSON & MORELAND
ENGINEERS & CONSULTANTS
Design and Supervision of Construction
Reports—Examinations—Appraisals
Machine Design—Technical Publications
BOSTON NEW YORK

WESTCOTT & MAPES INC.
Architects & Engineers
Power Plants Public Utilities
Industrial Plants
New Haven, Conn.

FRANK LEDERMANN, E.E.
Registered Patent Attorney
154 Nassau Street, New York 7, N. Y.
Telephone: BEekman 3-2936

THE J. G. WHITE
Engineering Corporation
Design—Construction—Reports—
Appraisals
80 BROAD STREET NEW YORK

LOCKWOOD & ANDREWS
CONSULTING ENGINEERS
Electrical, Mechanical, Structural,
Civil, Industrial, Municipal, Hydrology
Reports, Valuations, Rate Studies
Design, Supervision, Investigations
Union Nat'l. Bank Bldg., Houston, Texas

Fellow AIEE
SAMUEL B. WILLIAMS
CONSULTING ENGINEER
Forty Years Bell System Experience in the development and design of Electrical Communication and Computing Systems
Automatic Switching Systems
Patent Technical Advisor
366 Clermont Avenue, Brooklyn 5, New York

Alcoa broke trail for the giant steps to follow

Marching uphill and down with giant strides, Alcoa Aluminum Cable Steel Reinforced carries the energy that brightens homes, powers factories, moves trolleys and trains.

Old stuff to utility men, surely.

But not to the young Aluminum Company of 40 years ago. Scoffed at then, for advancing the idea that aluminum, an unknown metal, might help carry the nation's power, Alcoa nevertheless drove ahead, bound to test its idea.

Tested and proved, aluminum transmission met still another roadblock. No manufacturer cared to introduce this new wire commercially. So the young company—just 21 years away from a little shed on Pittsburgh's Smallman Street—set up its own cable stranders. Alcoa Aluminum Cable was born.

Then came the problems. Aluminum alone wasn't strong enough under many conditions; a steel core was added making it even stronger than other conductors. Alcoa ACSR was born. Increased strength permitted the economy of higher tensions and longer spans; vibration threatened to create fatigue, shorten life of conductors. Alcoa Research developed armor rods and dampeners to counteract it.

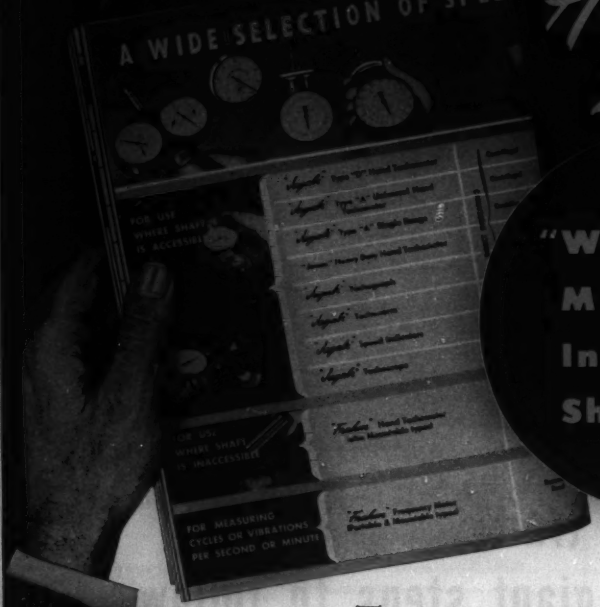
The job isn't done. It never will be. Research by Alcoa—at New Kensington, Pa., across the Texas plains; in its unique testing laboratory at Massena, N. Y.—is going on right now. Alcoa, pioneer in ACSR, will have the answers.

ALCOA

ALCOA CABLE AND ACCESSORIES

This Handy Selection Chart

Answers the Question...



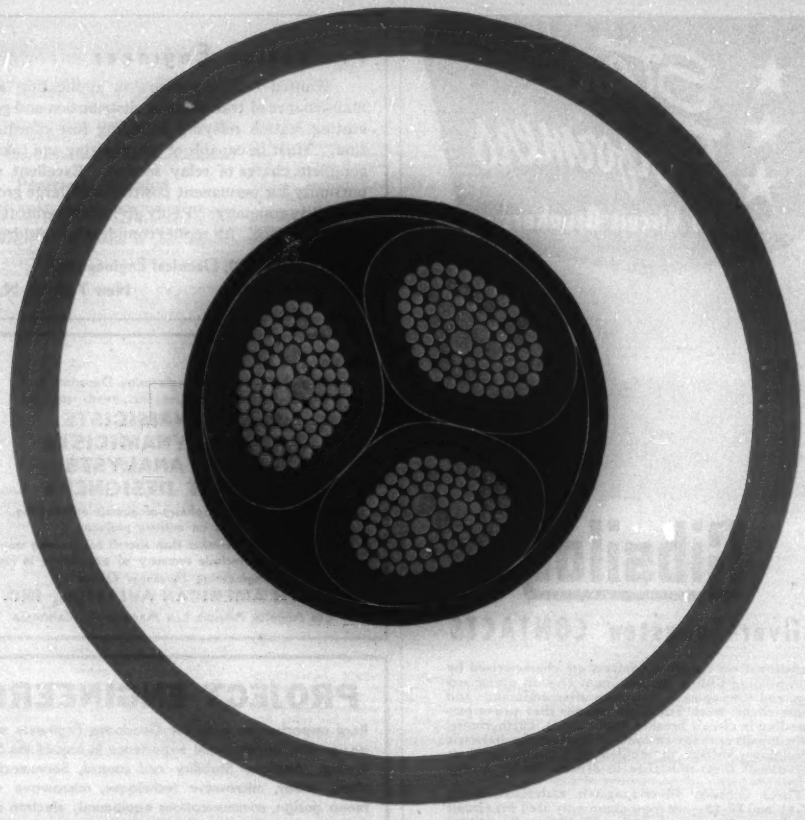
"What Speed Measuring Instrument Shall I Use?"

The quick-reference selection chart and index, illustrated above, tells you at a glance which type of Biddle instrument to use for your particular speed measuring problem. This handy guide is but one of many helpful features found in a newly-published bulletin, which contains descriptions, illustrations, and other data on our resonant-reed, chronometric, and centrifugal types of high quality speed measuring instruments. We would be pleased to send you a *free* copy of this new Biddle bulletin with selector chart. Your request will bring it to you promptly. Simply ask for Bulletin 35-EE.

JAMES G. BIDDLE CO.

Electrical & Scientific Instruments

1316 ARCH STREET, PHILADELPHIA 7, PA.



When you buy a Simplex Paper Insulated Cable:—

—Experienced cable engineers will make careful field studies of your operating conditions and special problems and will design a special Simplex Paper Cable to give you efficient service. If you prefer, the cable will be manufactured to your specifications.

—The insulating paper and the oil have been selected after much research to find materials that are completely compatible and will give you the operating characteristics you want in your cable.

—The equipment used to manufacture your cable will be completely up-to-date. The tensions, overlays, vacuums, impregnating machinery are all automatically controlled and all are carefully chosen to produce optimum results in the finished cable.

—The work will be done by experienced workmen under expert supervision.

—Tests will be made during manufacture and before shipment to be sure the cable meets your specifications and our rigid requirements.

—The cable you will get will be your cable — custom-made for you.

Bulletin #109 — Simplex Paper Insulated Cable — will be sent upon request.

Simplex

WIRES & CABLES

SIMPLEX WIRE & CABLE CO., 79 SIDNEY ST., CAMBRIDGE 39, MASS.

Gibsiloy

Silver-Tungsten CONTACTS

Gibsiloy silver-tungsten contacts are characterized by non-welding properties, minimum erosion under arcing, and low contact resistance after endurance and short circuit tests. For these reasons they prove outstanding in circuit breaker applications. Furthermore, Gibsiloy silver-tungsten contacts increase the dielectric breakdown voltage in molded case circuit breakers because of their resistance to erosion under arcing.

Three Gibsiloy silver-tungsten materials—W-10, W-13, and W-15—are most commonly used for circuit breaker applications. Gibsiloy W-10 has the lowest contact resistance of the group and therefore is most often used where one set of contacts must carry current as well as break the arc. Gibsiloy W-15 has the greatest resistance to arcing under erosion and therefore finds the most extensive application in arcing tips. Gibsiloy W-13 is intermediate in its properties as compared to W-10 and W-15. It is used for current carrying contacts where greater arcing resistance than afforded by W-10 is required; also, for arcing contacts where lower contact resistance is needed than is furnished by W-15.

The properties of these grades of Gibsiloy silver-tungsten contacts are:

	Conductivity (% I.A.C.S.)	Hardness (Rockwell B)
Gibsiloy W-10	67%	55
Gibsiloy W-13	58%	85
Gibsiloy W-15	47%	90

The application of silver-tungsten contacts to circuit breakers is illustrative of the capability of Gibson Electric Company to solve contact problems for any type of equipment. Write for contact recommendation data sheet for help on your problem.

Gibsiloy ELECTRICAL CONTACTS — Manufactured by GIBSON ELECTRIC COMPANY, 8348 Frankstown Ave., Pittsburgh 21, Pa.

Protection Engineer

Wanted with experience in application and maintenance of transmission, distribution and generating station relaying including fuse coordination. Must be capable of reorganizing and taking complete charge of relay section. Excellent opportunity for permanent position with large growing utility company. Reply giving age, education and experience. All replies confidential. Address:

Box 730, Electrical Engineering,
500 Fifth Avenue New York 18, N. Y.

ENGINEERS

Rapidly expanding Engineering Department of North American Aviation, Inc., needs qualified

AERODYNAMICISTS
THERMODYNAMICISTS
STRESS ANALYSTS
AIRCRAFT DESIGNERS

and specialists in all phases of aircraft engineering, for work on military projects.

Experience in fields other than aircraft engineering may be adaptable. Please include summary of experience in reply.

Engineering Personnel Office
NORTH AMERICAN AVIATION, INC.
Los Angeles Airport, Los Angeles 45, California

PROJECT ENGINEERS

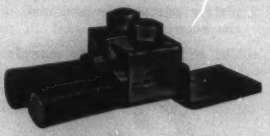
Real opportunities exist for Graduate Engineers with design and development experience in any of the following: Airplane Stability and control, Servomechanisms, radar, microwave techniques, microwave antenna design, communications equipment, electron optics, pulse transformers, fractional h.p. motors.

SEND COMPLETE RESUME TO EMPLOYMENT OFFICE.

SPERRY GYROSCOPE CO.,
DIVISION OF THE SPERRY CORP.
GREAT NECK, LONG ISLAND

Ilsco

ELECTRICAL CONNECTORS
●
MANY TYPES IN ALL SIZES
●
COOLER, MORE ECONOMICAL CONNECTORS
●



Fill out and mail for 54-page illustrated catalog.

Name .....
Firm Name .....
Address .....

ILSCO COPPER TUBE & PRODUCTS, INC., Cincinnati 27, Ohio

CLASSIFIED ADVERTISING

For help and situations wanted, $0.60 per line for AIEE members, others $1.00. Sale and purchase of used machinery, etc., $1.50 per line, minimum 5 lines, maximum 30 lines, not available to dealers.

Positions Wanted

LICENSED PROFESSIONAL ENGINEER, Member AIEE, Electrical Degree, 14 years experience in electrical factory design, training administration, and public speaking desires position as plant engineer, factory consultant, or administrative assistant. Address: Box 732, ELECTRICAL ENGINEERING, 500 Fifth Avenue, New York 18, N. Y.

RESEARCH AND ENGINEERING EXECUTIVE; E.E., M.I.T. grad. plus postgrad. Math. Experienced electric utility (20 yrs.) and manufacturing (6 yrs.) executive, specializing in electromechanical research and development. Well qualified for Director of Research, Chief Engineer or overall management. Many patents. East. Address: Box 733, ELECTRICAL ENGINEERING, 500 Fifth Avenue, New York 18, N. Y.

REPRESENTATIVE—Electrical Sales and Service for West Coast. 20 years sales and engineering experience. Member of A.I.E.E. and Registered Engineer, State of Cal. Address: Box 734, ELECTRICAL ENGINEERING, 500 Fifth Avenue, New York 18, N. Y.

Positions Open

ELECTRONICS ENGINEER—Well known, 40 year old manufacturer of electrical and electronic instruments wants engineer experienced in design of radio electronic apparatus at high radio frequencies, for the development of military and civilian test equipment. Address: Box 697, ELECTRICAL ENGINEERING, 500 Fifth Avenue, New York 18, N. Y.

LIGHTING ENGINEER—Experienced lighting engineer, capable design, selection and application of lighting for generating plants, electric substations, industrial plants and office buildings, wanted by large consulting firm located in New York City. Applicant should be qualified for solution of all technical problems related to lighting engineering. Please furnish complete information including age, education, and experience record. Address: Box 726, ELECTRICAL ENGINEERING, 500 Fifth Avenue, New York 18, N. Y.

ELECTRICAL ENGINEER for fast growing electric utility company in South America. Electric utility company experience required. Opportunity to take on responsibility rapidly. Preferable age 35 or under. Knowledge of Spanish desirable but not necessary. Address: Box 727, ELECTRICAL ENGINEERING, 500 Fifth Avenue, New York 18, N. Y.

TRANSFORMER ENGINEER experienced in design of small units; location, small community Western New York State; education, age, experience and salary expected. Address: Box 728, ELECTRICAL ENGINEERING, 500 Fifth Avenue, New York 18, N. Y.

ENGINEERING SCHOOL in South has openings for a Professor of Electrical Engineering to teach graduate and undergraduate communications work ($6,000 for nine months, extra income for summer teaching, Ph.D. or D.Sc.) instructors ($2700 for nine months, extra income for summer teaching, B.S., may obtain M.S. in three years) and Graduate Assistants who may obtain M.S. in one year ($1000 for nine months, extra income for summer teaching). Address: Box 735, ELECTRICAL ENGINEERING, 500 Fifth Avenue, New York 18, N. Y.

ELECTRICAL SWITCH DESIGNER—Electrical or mechanical engineering degree or equivalent. Experienced designing switches, cutouts and protective devices. Ability to translate original ideas to paper and carry through to point of manufacture. 25 to 40 years of age. Brooklyn plant. Salary commensurate with ability—$4000–$6000. Address: Box 736, ELECTRICAL ENGINEERING, 500 Fifth Avenue, New York 18, N. Y.

WANTED: Mechanical Engineer with 5 years experience in stress analysis and mechanical design of rotating electrical equipment. Must be capable of supervising design and drafting personnel. Excellent opportunity for qualified man with long established mid-western concern. Address: Box 737, ELECTRICAL ENGINEERING, 500 Fifth Avenue, New York 18, N. Y.

WANTED: WELDING ENGINEER—College graduate with stainless steel experience preferred. Must be familiar with resistance welding, inert gas welding, torch welding, brazing and soldering. To work with shop troubles concerning welding design or shop operations. Excellent job in an interesting field. State qualifications fully. Address: Box 738, ELECTRICAL ENGINEERING, 500 Fifth Avenue, New York 18, N. Y.

ELECTRONICS ENGINEER with experience in the development of measuring and controlling apparatus for aircraft. Age—under 30. Location—Southern New England. Address: Box 739, ELECTRICAL ENGINEERING, 500 Fifth Avenue, New York 18, N. Y.

WANTED: Large Foreign Electric Utility System requires engineer for General Operating Superintendent three large interconnected Hydro-Electric Generating Stations. Must be thoroughly experienced operation and maintenance generating equipment and scheduling water usage from seasonal storage reservoirs. Address: Box 740, ELECTRICAL ENGINEERING, 500 Fifth Avenue, New York 18, N. Y.

ELECTRICAL ENGINEER—Recent graduate of recognized college or university for supervisory position in plant engineering department of large chemical plant producing synthetic resins. Salary commensurate with ability and experience. Submit full particulars as to qualifications. Location, Midwest. Address: Box 741, ELECTRICAL ENGINEERING, 500 Fifth Avenue, New York 18, N. Y.

CHIEF ENGINEER, 35–50, electrical graduate, with considerable experience covering direction of engineering personnel, to take charge of design and development of industrial and governmental electronic program. Salary, $8000–$10,000 a year. Some traveling. Location, Washington, D. C. Y-1645.

DESIGNER to assist in the design of electronic analogue computers. Should be interested and experienced in electronics in general, and should be a good mathematician. Prefer man who has worked on flight simulators, servo mechanisms and advance circuit theory. Salary, about $5400 a year to start, with ten per cent increase in six months. Location, Pennsylvania. Y-1891.

ENGINEERING TEACHING PERSONNEL for electrical engineering department in connection with power and communication work. Will consider recent graduates. Duties will vary. Some will teach in communications, some in the laboratory and some in power work. Salaries open, depending on qualifications. Location, New York, N. Y. Y-1904.

ELECTRICAL SUPERINTENDENT, 35–50, electrical graduate, with at least ten years' construction and operation experience, preferably in mining field, to be responsible for operation of existing steam and hydroelectric plants and construction of additional capacity. Salary, $6000 a year. Location, New Foundland. Y-1915.

CHIEF INSPECTOR, 26–35, technical graduate, electrical or mechanical, with specialized experience in quality control of precision products, both small and large, used mainly for the indicating, recording and control of temperature and pressures. Must know modern inspection methods from receipt of raw materials, through foundry, heat treating, welding, plating, light and heavy machining, to accurate assembling and calibrating. Tool inspection also involved. Supervisory experience essential. Salary, $4500 a year. Location, Connecticut. Y-1919.

INSTRUMENT SALES ENGINEERS, 25–40, with B.S. degree in electrical engineering or physics. Salary and expenses. Territories, East and Midwest. Y-1924.

ENGINEERS. (a) Engineering Manager, 30–45, B.S. in E.E. including communications or electronics. Industrial experience in radar or communications systems design with ability to administer and direct an engineering activity. Will be responsible for development and manufacture of microwave radar systems, test equipment and electronic computers including the supervision and direction of a group of engineers, technicians and mechanical and electrical assemblers. Salary, $8710 a year. (b) Section Head—Equipment Development, 25–40, S.B. or S.M. in E.E. and at least one year in design of large scale electronic equipment and administration of engineers; radar systems or components; communication equipment; industrial electronic controls. Supervision of engineers and technicians working on electronic equipment development. Salary, $5520–$7080 a year. Location, Massachusetts. Y-1935.

ELECTRICAL ENGINEER, young, who has ability to write, preferably in the patent line. Work will be in connection with the writing of U. S. patent specifications and amendments. Background in communications would be particularly helpful. Salary dependent upon applicant. Location, New York, N. Y. Y-1947.

ASSISTANT PROFESSOR in electrical engineering, with at least a Master's degree, who has majored in the power field, to teach engineering courses. Salary, $3400 for nine months. Location, Texas. Y-1955-R5400.

ENGINEERS. (a) Electrical, to act as specialist on equipment standards for all electrical equipment and machinery. Will be responsible for developing and recommending procedures and policies for coordinating, expediting, initiating such standards. (b) Electrical, same as above, for electrically and electronically operated devices, also generators, transformers, dynamotors. (c) Electrical, same as above, for electronic equipment and components. (d) Electrical, same as above, for electrical equipment and end items. (e) Electrical, same as above, for electronic equipment and end items. Salary, $6255 a year. Headquarters, Washington D. C. Y-1960.

ENGINEERS for work covering computers, servos, amplifiers, instrumentation, small mechanisms in aircraft simulation for complete training equipment. (a) Electrical (electronics) engineers, project engineers, designers, recent graduates. (f) Electrical (electronics) production and manufacturing engineers for supervisory manufacturing and production positions. Actual electronic production supervision experience essential. (g) Field Service Men, electronic-electro-mechanical. Aviation background desirable. Recent graduates or experienced men. Will be trained at plant for field work. Single men preferred. Liberal expense and travel allowances. Location, upstate New York. Y-1974.

ENGINEERS. (a) Recent graduate physicists, trained in mathematics; to carry out data analyses on experimental results of radar work. (b) Senior engineers with broad training and experience in any one of the following fields: Antenna design and RF plumbing, circuit synthesis analysis and design (including both pulse and microwave circuits), radar equipment design and construction, and microwave communication. Salaries open. Location, Metropolitan Boston, Massachusetts. B-1556.

Engineering Societies **Personnel Service, Inc.**

New York	Chicago	Detroit	San Francisco
8 West 40th St.	84 East Randolph St.	100 Farnsworth Ave.	57 Post St.

In applying for positions advertised by the Service, the applicant agrees, if actually placed in a position through the Service as a result of these advertisements, to pay a placement fee in accordance with the rates as listed by the Service. These rates have been established in order to maintain an efficient, non-profit personnel service and are available upon request. This also applies to registrants whose notices are placed in these columns.

Apply by letter addressed to the key number and mail to New York Office. When making application for a position include six cents in stamps for forwarding application to the employer and for returning when necessary. A weekly bulletin of engineering positions open is available to members of the co-operating societies at a subscription rate of $3.50 per quarter or $12 per annum, payable in advance.

Men Available

ELEC ENGR, BSE 1939; age 33; conscientious worker; 5 yrs exper applied electronics; 2 yrs des and constr fractional kva pwr transformers; 2 yrs devpmt supersonic frequency transformers and inductors. Desires pos in Southwest. E-390.

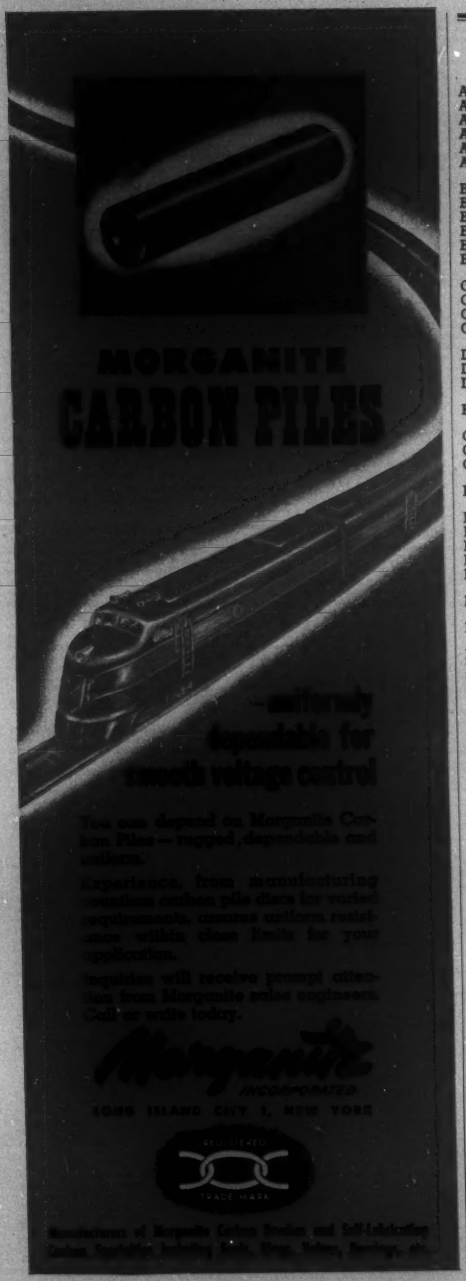
Positions Available

EDITORIAL ASSISTANT, electrical or mechanical graduate, with industrial experience in power plant, refrigeration, pumping, etc., to prepare technical articles covering maintenance and operation of power plants and auxiliaries. Salary, $3600–$6000 a year. Location, New York, N. Y. Y-1509.

ELECTRICAL ENGINEER with plant engineering experience, to supervise the work of electrical draftsmen, covering application and layout of mining and material handling equipment, and power distribution. Salary open. Location, eastern Pennsylvania. Y-1513.

ELECTRICAL ENGINEER, specifications, with several years' utility experience, to be assistant to engineer in charge of power cable recommendations, applications and calculations. Salary, $4800–$6000 a year. Location, New York Metropolitan Area. Y-1592.

PLANT ENGINEER, 40–45, preferably electrical graduate, with electrical maintenance experience in metal manufacturing industry, including safety supervision, to take general charge of machine shop, stamping, plating, polishing, electronic heating, etc. Salary, $6000–$8000 a year. Location, northern New Jersey. Y-1644.


MORGANITE
CARBON PILES
—uniformly dependable for smooth voltage control
You can depend on Morganite Carbon Piles—rugged, dependable and uniform.
Experience from manufacturing countless carbon pile discs for varied requirements, ensures uniform resistance within close limits for your application.
Inquiries will receive prompt attention from Morganite sales engineers. Call or write today.
Morganite Incorporated
LONG ISLAND CITY 1, NEW YORK
REGISTERED
TRADE MARK
Manufacturers of Morganite Carbon Brushes and Self-Lubricating Carbon Bearings, Industrial Seals, Slings, Rubber, Bearings, etc.

INDEX TO ADVERTISERS

Acme Electric Corp. 40 A
Allis-Chalmers Co. 2nd cover, 24 A–25 A
Aluminum Company of America 53 A
Anaconda Wire and Cable Co. 7 A
Arnold Engineering Co. 20 A
Audio Development Co. 42 A

Belden Manufacturing Co. 2 A
Bell Telephone Laboratories 10 A
Bethlehem Steel Co. 33 A
Biddle, Co., Jas. G. 54 A
Bruning Co., Inc., Chas. 50 A
Burlington Instrument Co. 59 A

Classified Advertising 57 A
Cole Electric Co. 60 A
Copperweld Steel Co. 41 A
Cornell-Dubilier Electric Corp. 19 A

Dow Corning Corp. 16 A
Du Mont Laboratories 34 A
Du Pont de Nemours and Co., Inc., E. I. 12 A

Electric Fish Screen Co. 52 A

General Electric Co. 8 A–9 A, 17 A, 35 A, 44 A, 51 A
General Radio Co. 18 A
Gibson Electric Co. 56 A

Hubbard and Co. 11 A

Ilsco Copper Tube and Products Co., Inc. 56 A
Indiana Steel Products Co. 38 A
Industrial Notes 16 A, 26 A, 30 A, 44 A, 48 A
Insulation Manufacturers Corp. 4 A
I-T-E Circuit Breaker Co. 3rd cover

Kerite Co., The 13 A

Leeds and Northrup Co. 28 A

Measurements Corp. 47 A
Moloney Electric Co. 14 A–15 A
Morganite, Inc. 58 A
Mycalex Corp. of America 42 A

National Varnished Products Corp. 37 A
North American Aviation, Inc. 56 A

Ohio Brass Co. 31 A
Ohmite Manufacturing Co. 49 A
Okonite Co. 5 A
O.Z. Electrical Manufacturing Co., Inc. 32 A

Personnel Service, Inc. 57 A
Porcelain Products, Inc. 39 A
Porcelain Insulator Corp. 40 A
Power Equipment Co. 47 A
Professional Engineering Directory 52 A

Radio Corporation of America 4th cover
Rome Cable Corp. 21 A
Rowan Controller Co., The 27 A

Simplex Wire and Cable Co. 55 A
Smith Paper, Inc. 6 A
Sorensen and Co., Inc. 44 A
Sorgel Electric Co. 48 A
Special Publications—AIEE 26 A
Sperry Gyroscope Co. 56 A
Sprague Electric Co. 45 A
Stackpole Carbon Co. 22 A
Standards—AIEE 40 A
Struthers-Dunn, Inc. 30 A

Trumbull Electric Manufacturing Co. 23 A

United States Rubber Co. 43 A
United States Steel Corp. 46 A
Universal Clay Products Co. 59 A

Vickers Electric Division 59 A

Welwyn Electronic Components, Inc. 26 A
Westinghouse Electric Corp. 29 A
Weston Electrical Instrument Corp. 36 A

Burlington

GENERATOR VOLTAGE REGULATOR TYPE WA

Designed for use in regulating the voltage of A.C. generators in Stationary, Mobile or Marine installations.

Direct rheostatic action provides a simple, effective and automatic means of regulating voltage by performing the function of an automatic field rheostat.

Rating of rheostatic element is 2 amperes maximum exciter shunt field current at full load and power factor. Maximum sigma watts is 50 watts.

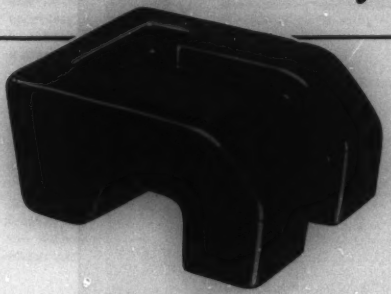
FEATURES

* DIRECT ACTING
* FAST RESPONSE
* AUTOMATIC CONTROL
* SMALL, COMPACT, SELF CONTAINED
* RUGGED CONSTRUCTION
* RHEOSTATIC ACTION
* INEXPENSIVE

Inquiries for complete information and engineering services solicited.

BURLINGTON INSTRUMENT COMPANY
DEPT. L29
BURLINGTON, IOWA

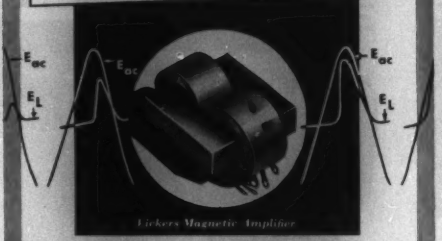
LEADS A *Double Life*



This third rail insulator has a double job . . . first, it must have the high dielectric strength to withstand heavy current charges. Second, it must be sturdy enough to stand up under the incessant pounding of passing trains. Add to these the inherent qualities of resistance to temperature changes, to moisture, to most acids and you have the reason so many manufacturers turn to Universal for their insulator needs. An experienced Universal engineer will be glad to help with your insulator requirements. Get in touch today.

THE UNIVERSAL CLAY PRODUCTS CO.
1560 EAST FIRST STREET SANDUSKY, OHIO
TRADE MARK

NOTICE
OF IMPORTANCE TO THE ELECTRICAL INDUSTRY



VICKERS ELECTRIC DIVISION, Vickers Inc., Announces a complete Research and Development Section available for your technical problems in relation to the following—

MAGNETIC AMPLIFIERS
MAGNETIC AUDIO AMPLIFIERS
STATIC VOLTAGE REGULATORS
STATIC MOTOR SPEED CONTROLS
POWER SATURABLE REACTORS
RECTIFIERS
PHOTOELECTRIC CELLS
SERVOMECHANISMS
MAGNETIC FLUID CLUTCHES
SPECIAL MOTORS AND GENERATORS
TRANSFORMERS • ARC-WELDERS
CONTROLLED POWER RECTIFIERS FOR ELECTRO-CHEMICAL PROCESSES

The fundamental schemes employed in many of the above involve general use of tubeless amplifier circuits —Magnetic Amplifiers.

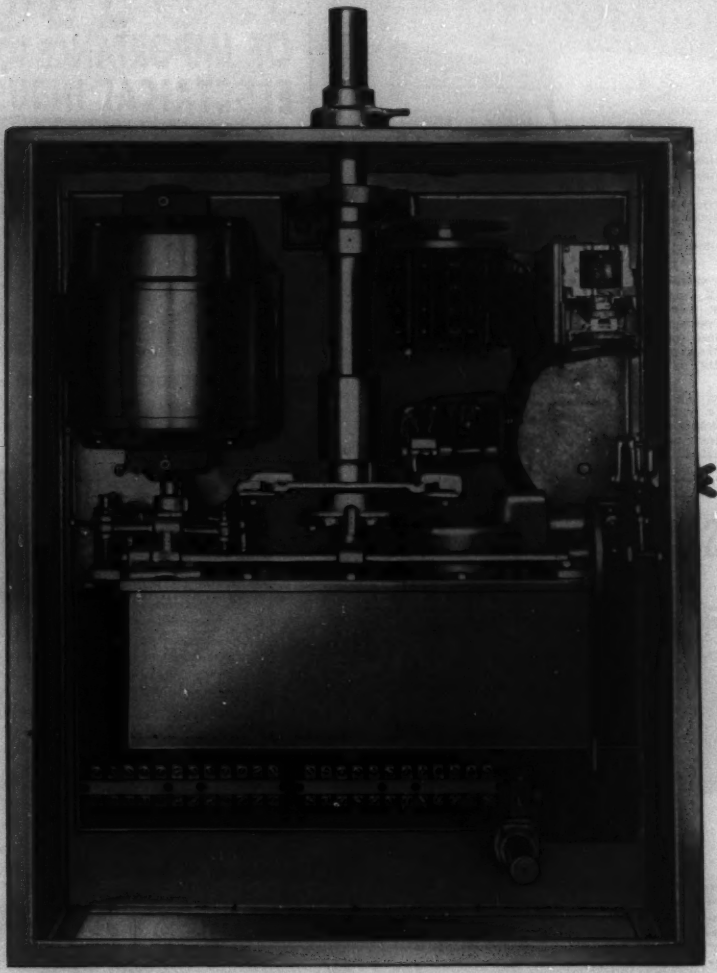
For information regarding application of the above relative to your requirements, you are cordially invited to consult our Engineering Department.

VICKERS ELECTRIC DIVISION
1815 LOCUST ST, ST. LOUIS 3, MISSOURI
A UNIT OF THE SPERRY CORPORATION

B-2

Cole Electric Co.

8439 Steller Drive TExas 0-4701 Culver City, Calif.

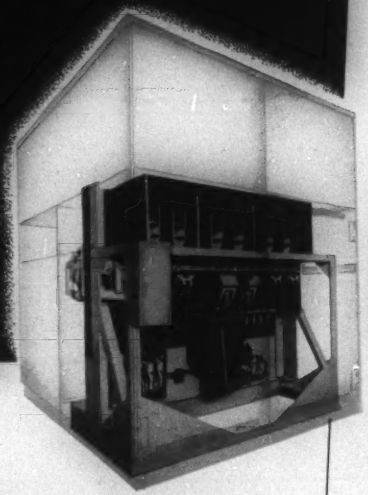


MOTOR MECHANISM
FOR OPERATING
DISCONNECTING SWITCHES
TYPE CG-1
(See Bulletin 45A.)

A 6000-AMPERE TRUCK-MOUNTED DRAW-OUT TYPE CIRCUIT BREAKER

for Main-, Bus-Tie-, and Feeder-Breaker Applications

Another I-T-E "first"!



AGAIN I-T-E LEADS the way in Switchgear design! The new I-T-E LG Circuit Breaker is the first 6000-Amp. breaker to be offered in a truck-mounted, draw-out type.

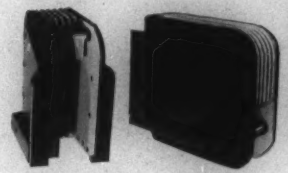
The rugged, heavy-duty Type LG is the ideal breaker for applications where breaker operations are relatively few, and where high interrupting ability — with moderate operating speed — is needed. The LG is designed and built to carry a full load continuously for long periods of time with a minimum of temperature rise.

I-T-E's Truck-Mounted Draw-Out Type LG Circuit Breaker is another example of I-T-E leadership in producing custom-made circuit breakers and switchgear equipment to meet the exacting requirements of individual customers. It is exclusively an I-T-E product — designed and built where Switchgear is a business, not a side line.

The I-T-E representative in your locality will be glad to assist and advise you on adapting the new truck-mounted LG breaker to your electrical distribution system. Use his services without obligation. For complete technical and application data, write for LG (Catalog) 1104.

CONSTRUCTION FEATURES OF THE I-T-E TYPE LG CIRCUIT BREAKER

MAIN CONTACTS are built up of copper bars with silver alloy inserts to provide silver-to-silver contact. Silver facings are durable — more than 40,000 openings and closings do not cause perceptible wear of the contact faces. Intermediate and arcing contacts protect main contacts during opening and closing operations.



ARC CHUTES are magnetic blow-out type. Magnetic vanes, mounted outside the insulating barriers on each side of the contacts, are magnetized upon opening of the intermediate contacts, and the resulting magnetic field forces the arc into the extinguishing chamber. Arcing time is short, arc is completely confined, heavy currents are safely handled in small space.

CONTROL MECHANISM is centrally located. A small door in the main enclosure panel gives access to controls. Actual mechanism is so designed that it automatically locks the truck when in *Disconnected, Test,* or *Operating* position. The truck can be moved to any of these positions without opening the main compartment doors; thus complete protection is given to the operator and the mechanism. An interlocking mechanism prevents the truck from being moved into or out of the operating position unless the breaker has been tripped and all contacts opened.

APPLICATION RATINGS—TYPE LG CIRCUIT BREAKERS

	PANTOGRAPH-MOUNTED	TRUCK-MOUNTED
600 V AC	2000-3000 A	4000-6000 A
250 V DC	2000-5000 A	6000-10,000 A

2-, 3-, and 4-Pole. Electrically operated.
75,000 and 100,000 amperes R.M.S. Interrupting Rating.

I-T-E R&IE *

The Leader In Technical Excellence

I-T-E CIRCUIT BREAKER COMPANY, 19th & HAMILTON STREETS, PHILADELPHIA 30, PA.
31 OFFICES IN UNITED STATES • In Canada, EASTERN POWER DEVICES, Ltd., TORONTO
SWITCHGEAR • UNIT SUBSTATIONS • ISOLATED PHASE BUS STRUCTURES • AUTOMATIC RECLOSING CIRCUIT BREAKERS
*FOR POWER SWITCHING EQUIPMENT, REFER TO RAILWAY AND INDUSTRIAL ENGINEERING CO., AN I-T-E ORGANIZATION

The RCA List of Preferred Type Receiving Tubes fulfills the major engineering requirements for future receiver designs.

Most likely to succeed . . .

RCA preferred type tubes for AM, FM, and TV receiver designs

WHETHER IT'S GLASS, metal, or miniature—RCA *preferred type* receiving tubes will serve your major requirements for a long time to come . . . and RCA preferred types are the tubes you can bank on for your future designs.

These RCA receiving types are especially recommended because their wide-spread application permits production to be concentrated on fewer types. Longer manufacturing runs reduce costs—lead to improved quality and greater uniformity. These benefits are shared by you and your customers.

RCA Application Engineers are ready to suggest the best preferred types for your receiver design requirements. Just contact our nearest regional office—or write RCA, Commercial Engineering, Section 39BR, Harrison, New Jersey.

The Fountainhead of Modern Tube Development is RCA

TUBE DEPARTMENT

RADIO CORPORATION of AMERICA

HARRISON, N. J.